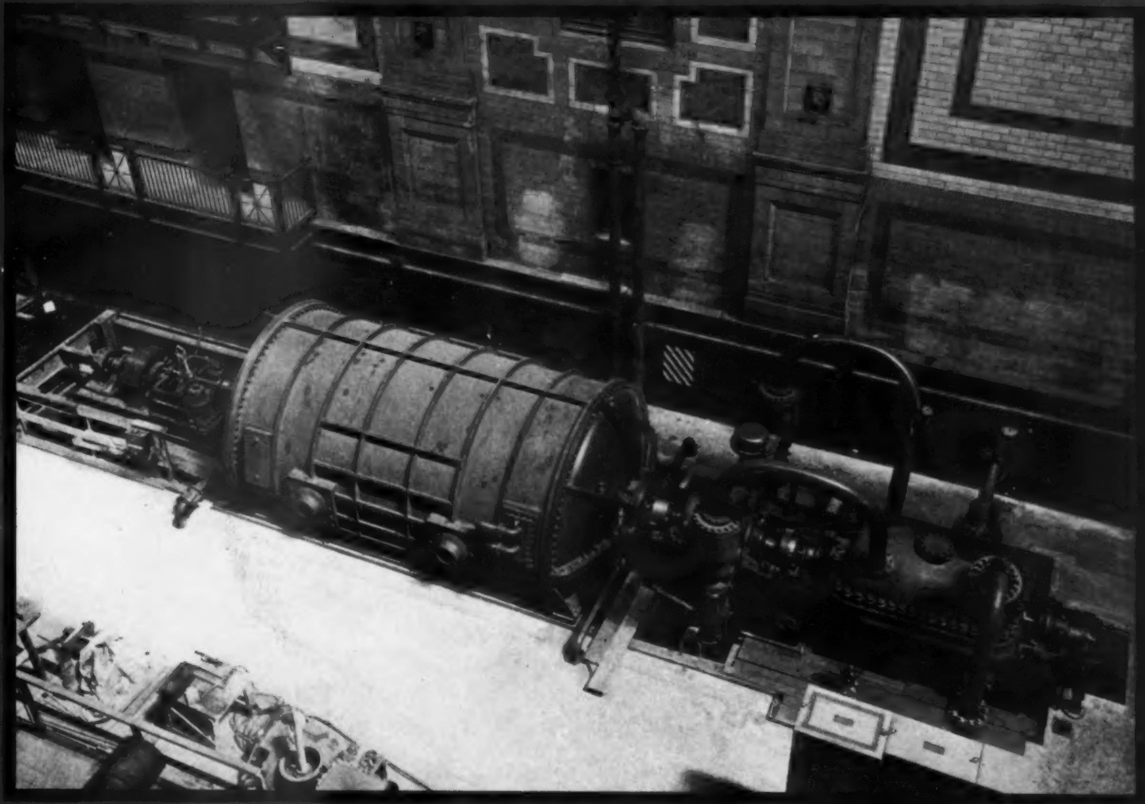
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 9, No. 12 | JUNE, 1938 | 25c a copy



High-pressure 53,000-kw turbine-generator at Waterside Station; see page 27

Extension to Riverside Station of The United Power Mfg. Co.

53,000-Kw, 3600-Rpm, Superposed Turbine for Waterside Station

Metallurgy of Power Plants

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINE NUMBER TWELVE

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FOR JUNE 1938

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Combustion is published monthly by Combustion Publishing Company, Inc., a subsidiary of Combustion Engineering Company, Inc., 200 Madison Avenue, New York. Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Treasurer; G. W. Grove, Secretary. It is sent gratis to consulting and designing engineers and those in charge of steam plants from 500 rated boiler horsepower up. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents. Printed in U. S. A. Publication office, 200 Madison Avenue, New York. Issued the middle of the month of publication.

Member, Controlled Circulation Audit, Inc.

EDITORIAL

Coal Research

With advancement in power plant practice the efficiency of coal utilization has steadily improved, as measured on an input-output basis. Further improvement upon the performance of the most up-to-date installations must be progressively less as the limitations inherent in the steam cycle are approached. This is demonstrated by the statistics issued by the Federal Power Commission covering the generation of electricity for public consumption. From 1920 through 1937 the pounds of coal per kilowatt-hour steadily decreased from 3 in 1920 to 1.43 in 1937, but during the last five years the reduction has been only from 1.47 to 1.43. This, of course, is an average for nearly 3800 plants, the most efficient of which are far under this figure. Much remains to be accomplished, however, in raising the efficiency of the poorer plants, particularly among industrials, to the level of the leaders in their class.

With further improvements in thermal performance limited, there is still opportunity for increasing the commercial or dollar efficiency through the selection of the correct coal for the particular conditions, thereby simplifying operating problems by reduced maintenance and outage. Credit for achieving the marked reduction in coal consumption per kilowatt-hour belongs to the designers and operators of power plants and their equipment, but as an aid to further progress specific information on the behavior of different coals under various conditions of burning is needed and would be welcomed not only by the designer of equipment but also the user as a guide to the selection of the most suitable equipment.

With some six thousand mines in the United States producing coals of various characteristics and sizes, and hardly any two power plants identical in design and operation, the great multiplicity and combination of factors involved becomes apparent.

The chemistry of coal has long been studied and data are available covering the analyses and other properties of coals from practically all seams. Also, some operating companies have accumulated helpful information on the performance of certain coals by trials in individual plants. But, despite this, there has been a dearth of information on just what goes on during the process of burning these various coals.

There is a growing appreciation of the desirability of giving more attention to coal selection, predicated upon a knowledge of its behavior in storage, in handling and in the furnace, its caking and clinkering characteristics and the mechanism of combustion. This has been brought about partly by developments in power station design and changes in operating practice and partly by the new marketing situation resulting from application of the National Bituminous Coal Act.

Constructive work in fundamental coal research has been conducted for some time at Carnegie Institute of Technology and the U. S. Bureau of Mines, but an added impetus to the solution of coal utilization problems was provided in 1935 by the formation of Bituminous Coal Research, Inc., under whose sponsorship projects are now being carried out by several universities and by Battelle Memorial Institute. Much of this research extends beyond the laboratory into the field of coal utilization where surveys are being made and tests conducted in actual installations. The question of coal segregation has been attacked, sizing has been studied and for the first time the reactions and behavior of coal on an underfeed stoker have been ascertained under service conditions. The program is far-reaching and much still remains to be accomplished.

During the eighteen-year period, from 1920 through 1937, despite a three-fold increase in electric output, the consumption of coal by the plants previously mentioned has remained practically the same. This has been due partly to improved efficiency and partly to the inroads of competitive fuels, particularly gas. In meeting this challenge the coal industry through the promotion of research in utilization is rendering a service to the power plant field as well as to itself.

Steam Washing

The extensive use of higher boiler pressures has been accompanied by the necessity of providing clean steam in order to avoid troublesome turbine deposits—a condition seldom obtaining with pressures under three hundred pounds. This has led to the wide use of steam washers by means of which the steam is washed by the relatively pure feedwater and the solids entrained in the steam are reduced to a minimum.

Many tests have been made on the purity of steam thus washed and have shown remarkably low solids content, ranging from 0.5 to 1 ppm when operating with very high boiler-water concentrations. From this it should not be inferred, however, that high boiler-water concentrations are always permissible, as this depends upon several factors including pressure, analysis of the boiler water, the steam liberation per cubic foot of drum and the type of boiler. Therefore, each case requires individual consideration.

Several methods have been evolved for testing the purity of steam. Among these are evaporation of the sample and testing by electrical conductivity. In the former method considerable time is required and much care is necessary in order to avoid contamination, whereas with the latter the presence of dissolved gases must be guarded against or corrections made for them. While it is possible to determine the purity of steam down to 0.5 ppm, or perhaps less, those experienced in making such measurements usually advise checking by two or three methods when the indicated purity is less than 1 ppm.

In the final analysis, however, the object is to reduce the steam purity to such a figure as will avoid trouble in operation. This should be the ultimate criterion of performance.

Extension to RIVERSIDE STATION of The United Power Mfg. Co.

By C. A. BUTLER,
United Light & Power
Engineering & Construction Co.

This addition consists of a 28,571-kva condensing turbine-generator supplied with steam at 825 lb, 825 F, from a single steam-generating unit fired with pulverized coal and having a continuous slagging furnace. The turbine design permits steam extraction to the existing 400-lb station header. The article reviews the preliminary engineering studies involved and traces the progress in design of steam-generating equipment since the initial installation was made in 1925.

THE rapid progress which has been made in the design of steam-generating equipment in a comparatively few years is shown by the development of the Riverside Station of the United Power Manufacturing Company. This station is located on the west bank of the Mississippi River about eight miles north of Davenport, Iowa. Its combined capacity of main generators is now 82,142 kva which, together with that of an older steam station and several small hydroelectric plants, serves Davenport, Ia., Rock Island and Moline, Ill., and the surrounding territory.

History

Riverside Station is a comparatively new power plant, it having been placed in service in 1925. The original installation consisted of four 1044-hp Heine boilers and one 25,000-kva turbine-generator. These boilers were of the cross-drum box-header type, designed for a maximum drum pressure of 440 lb per sq in., with combination convection and radiant superheaters arranged to raise the steam temperature to 700 F. A high-pressure economizer and a steel-plate induced-draft fan were installed in connection with each boiler. The fuel-burning equipment consisted of four 10-retort, 33-tuyère underfeed stokers. There were four forced-draft fans, con-

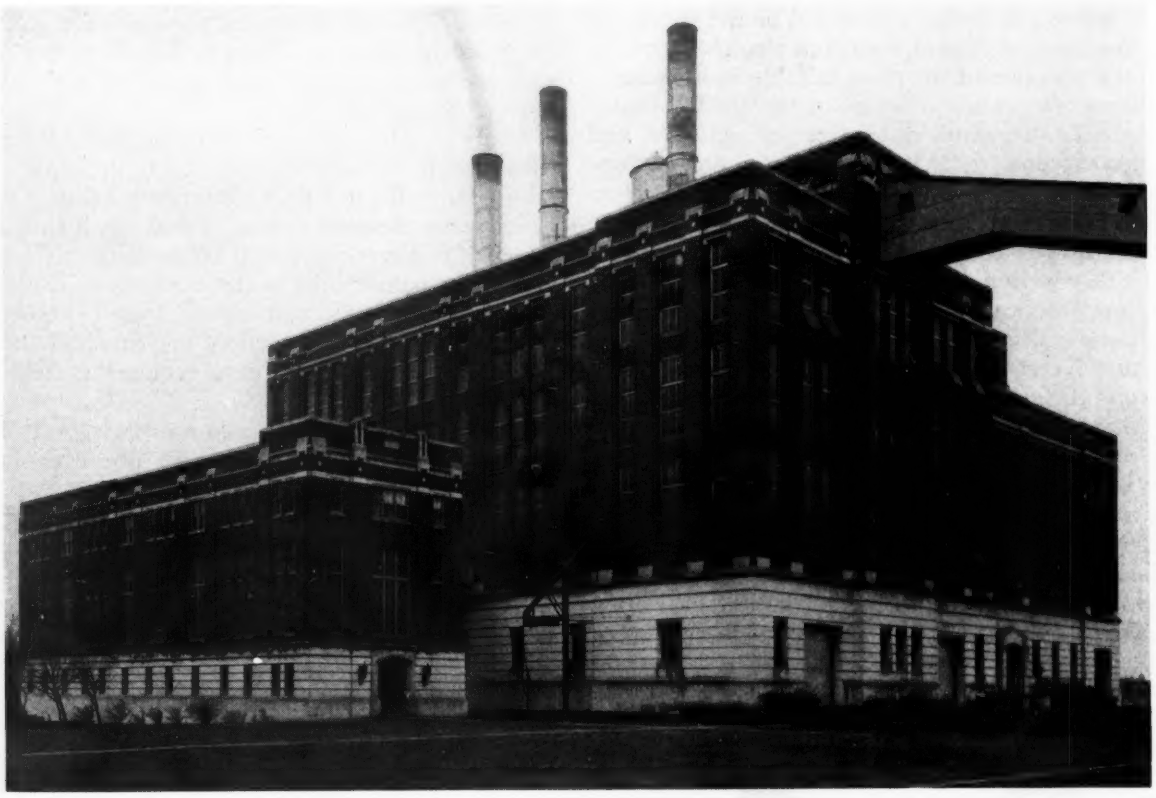

Fig. 1—Exterior view of Riverside Station

nected to a common air duct serving all the boilers. Air-cooled refractory settings were employed.

It was found that the maximum continuous output of each boiler as originally installed was 90,000 lb per hr and that operation at higher ratings, even for short periods, resulted in excessive furnace and stoker maintenance.

In 1929 a second turbine-generator of 28,571 kva capacity was installed. No additional boilers were put in at that time because the system load did not make it necessary to carry full load on both generating units simultaneously. About the same time one of the boilers was equipped with a water-cooled furnace. This change increased the availability of this boiler, as was expected, and greatly reduced furnace maintenance. The remaining three boilers were equipped with water-cooled furnaces in 1930 and 1931.

The fuel burned on the underfeed stokers was principally southern Illinois coal. In 1932 a strip mine was opened approximately sixty miles from the power plant. The coal from this mine could be delivered to the plant at considerably less cost than that then being used, but it ran high in moisture and had a low ash-fusion temperature; hence it could not be successfully burned on the underfeed stokers.

In order to take advantage of this supply of low-priced fuel, the stoker was removed from one of the boilers, the water-cooled furnace was altered and two pulverizers were installed. Direct firing and the intermittent slag tap method of removing the ash were employed. To provide preheated air for the mills, a small Ljungstrom air heater was installed with the gas passage in parallel with the economizer. This equipment was placed in service early in 1933. With the increased fuel burning capacity, and the reduction in draft loss through the economizer, as a result of diverting part of the flue gas through the air heater, the steaming capacity of the boiler was increased to 140,000 lb per hr. This installation was so successful that a second boiler was similarly altered later in the same year.

In 1934 natural gas became available at Riverside. This was supplied on a typical "dump gas" basis, and did not entirely replace coal as fuel. All the boilers were equipped for burning gas. The burners on the two boilers that had been provided with pulverizers were converted to combination gas and coal burners, and in the other boilers gas was burned over the stokers.

With both pulverized coal and gas firing, the superheat added to the steam in the radiant superheaters was reduced. Therefore these radiant superheaters were rebuilt not only to regain the lost superheat, but to raise the final stream temperature to 740 F.

By 1936 the increase in industrial and domestic use of gas had limited the amount available for use in the power plant. This fact, together with increased system load, made it necessary to remodel the remaining two boilers for pulverized coal firing, despite the fact that plans for additional boiler and turbine capacity were already being made. The changes were similar to those previously made on the other two boilers.

As a result of the changes in these four boilers since they were first installed, they can now carry both 400-lb turbines at maximum emergency capacity, and three boilers can carry both turbines at normal full load capacity, namely, 20,000 kw each. In the installation as originally made, three boilers were required to carry the original turbine at full load continuously.

1936–1937 Addition

Increased load on the system made it necessary to generate an appreciable amount of power at the Moline steam plant, located farther down the river on the east bank. Compared with Riverside, the economy of the Moline plant is poor and maintenance costs are high. The increase in load also indicated early need of increased capacity on the system. Modernization of the Moline plant by installing a superposed unit was considered. But investigations showed that it was more desirable to concentrate operations at the more modern Riverside Station and maintain the Moline plant for power-factor correction and standby service only.

Although the equipment at Riverside could not be considered obsolete, and the station was operating at a heat consumption of approximately 16,500 Btu per kw hr generated, it was obviously unwise to add new equipment designed for the steam conditions of 440 lb per sq in. and 740 F, without giving serious consideration to the possibilities of more economical operation obtainable with equipment designed for higher steam pressure and temperature. The use of a high-pressure superposed unit exhausting to the 400-lb header did not prove attractive for several reasons. First, with 400 lb exhaust pressure, the capacity of a superposed unit using steam at 1400 lb or less at the throttle would be too small to provide the additional system capacity required. Furthermore, the blading efficiency of so small a high-pressure turbine would have been comparatively low. It was thought that there was insufficient operating experience with pressures in excess of 1400 lb per sq in. to justify consideration of a higher pressure in order to increase the capacity of the superposed unit. Secondly, due to the fact that a portion of the base load of the system is carried by the hydroelectric plants, the new equipment would at times be required to operate at comparatively light loads. Finally, it would obviously be impractical to make the superposed turbine-generator available for use with steam from the 440-lb boilers.

The New Turbine-Generator

Further studies, taking into consideration fuel cost, equipment cost, expected character and amount of load, and other important factors, led to the selection of a 3600-rpm condensing turbine-generator designed for throttle steam conditions of 825 lb per sq in. and 825 F total temperature. Specifications were drawn up requiring that the turbine should be designed for these steam conditions, but should be able to carry full load, at reduced economy, with throttle steam of 400 lb and 740 F.

The turbine selected is a 21-stage G-E tandem-compound machine using impulse blading throughout. Eighteen stages are in the high-pressure cylinder. There are two rows of moving blades in the first stage and the other 17 stages in the high-pressure cylinder have one row of moving blades each. The low-pressure cylinder is of the double-flow type. There are nine admission valves in the steam chest. The eighth and ninth valves, which are used only when the turbine is operating with 400-lb steam at the throttle, admit steam directly to the fourth stage. A fulcrum shifting device, actuated by the steam pressure at the throttle, is incorporated in the

governing mechanism. At pressures above 500 lb the eighth and ninth valves are prevented from opening, and the full range of the governor is made available for operating the first seven valves. At pressures below 500 lb the governor is able to open all of the admission valves.

When the turbine is operating with 825 lb steam pressure at the throttle, all of the steam passes through the first stage. Inasmuch as the pressure in the first stage chamber under the heavier loads rises above 400 lb, it was found practical to provide for extracting steam from this turbine into the 400-lb header when the high-pressure steam generating equipment is in service and the machine is loaded above 22,000 kw. The design of the turbine permits 166,500 lb of steam per hour to be extracted at 400 lb per sq in., but until a second 900-lb pressure boiler is installed, the amount of high-pressure steam available will limit the extraction to 126,500 lb per hr.

Despite its versatility, this turbine has an economy under normal operating conditions, which is within one per cent of that of a turbine not having these features of large high-pressure steam extraction and the ability to carry full load with reduced throttle pressure. Furthermore, the economy when operating on 400 lb per sq in. is better than that offered by any turbine manufacturer when the machine installed in 1929 was under consideration.

The main generator driven by this turbine produces 13,800-volt, 3-phase, 60-cycle energy. Its capacity is 28,571 kva at 70 per cent power factor. Excitation for the main generator is provided by an exciter on the main shaft of the unit and the excitation for this main exciter is, in turn, provided by a pilot exciter which is also driven by the main shaft. This eliminates losses in the generator field rheostat during normal operation.

Since the major portion of the power from Riverside Station is transmitted by overhead lines, it was necessary to provide a source of power supply for the essential auxiliaries independent of the main generators and the main bus. The 1500-kw house-service generator driven by a non-condensing turbine, which was a part of the original installation, was inadequate to serve the enlarged plant; hence, a 2500-kw house-service generator was incorporated in the new turbine-generator unit. This is located between the main generator and the exciters. All of the auxiliaries in the station are supplied with power at 440 volts, 3-phase, 60-cycles, and the new house-service generator supplies power of these characteristics direct to the house-service bus.

Steam Generating Equipment

Since the new turbine could be operated at full load on steam from the existing boilers, only one 900-lb pressure boiler was considered. A boiler having sufficient capacity to carry full load on the new turbine, without extraction to the 400-lb header, was first contemplated. Due to the character of the coal to be burned, pulverizers were the only type of fuel burning equipment considered. The steam generating unit offered originally had a capacity of 225,000 lb of steam per hour, and was fired by two pulverizers. As the coal at times contains excessively high moisture, a considerable margin in pulverizer capacity was necessary to insure full boiler capacity under such conditions. Furthermore, with only one high-pressure boiler, it was desirable to be able to take a pulverizer out of service for maintenance without drastically reducing the capacity of the steam generating unit. Therefore, three pulverizers were finally selected, of a capacity such that under ordinary conditions two would supply enough steam to carry normal load on the turbine. With three pulverizers in service ample capacity is provided to take care of adverse fuel conditions.

By providing more capacity than originally planned in the forced- and induced-draft fans, it is possible to utilize most of the capacity of the three pulverizers under normal fuel conditions, and increase that of the steam generating unit to 300,000 lb of steam per hour.

The boiler installed is a C-E bent-tube three-drum type designed for a maximum pressure of 900 lb per sq in. Its drums are of welded construction and the heating surface in the boiler proper is 8020 sq ft. The superheater, which is located between the first and second banks of tubes, has sufficient surface (6400 sq ft) to raise the total steam temperature to 825 F when the output is 112,500 lb of steam per hour. At higher outputs the steam temperature is controlled through bypassing a portion of the gas around the superheater and thus maintaining the temperature at 825 F.

A 9480-sq ft continuous-loop economizer is located within the boiler setting in space provided between the two rows of tubes constituting the last bank. A gas bypass located entirely within the setting makes possible partial bypassing of the economizer. This serves two purposes. At low ratings gas is bypassed so as to increase its temperature entering the air heater and thus prevent its being cooled below the dew-point in the air heater. This reduces the danger of corrosion and plugging in the air heater. Since approximately one-third of the total draft loss occurs in the economizer, the gas bypass can be used if necessary at extremely high ratings to reduce the draft required at the induced-draft fan under adverse conditions. The feedwater enters the economizer at 212 F and is heated to 398 F at maximum rating. The feedwater regulating valves are located between the economizer and the boiler drum to prevent steam being generated in the economizer when bringing the boiler up to operating pressure.

The air preheater is of the Ljungstrom type, with its shaft horizontal. It is placed above the boiler and contains 14,400 sq ft of heating surface. The air temperature is raised to 305 F at 112,500 lb per hr steam output and to 394 F at the maximum steam output of 300,000 lb per hr.

The furnace is completely water cooled. It has a volume of 12,650 cu ft and the effective heat-absorbing surface in the furnace walls is 3825 sq ft. A steel casing encloses the entire furnace, boiler, economizer and superheater. The waterwall circulating tubes are located within the casing behind the furnace tubes, and are protected from the furnace heat by insulation in addition to the protection afforded by the furnace tubes.

Fuel is fired tangentially by twelve burners, three in each corner of the furnace. One burner in each corner is connected to each of the three pulverizers, so that one, two or three mills may be used as required without upsetting the tangential effect. In each burner provision is made for burning gas as well as coal. Gas and coal may be burned either individually or simultaneously. This feature is especially valuable because at times a limited amount of gas is available, but the amount is not

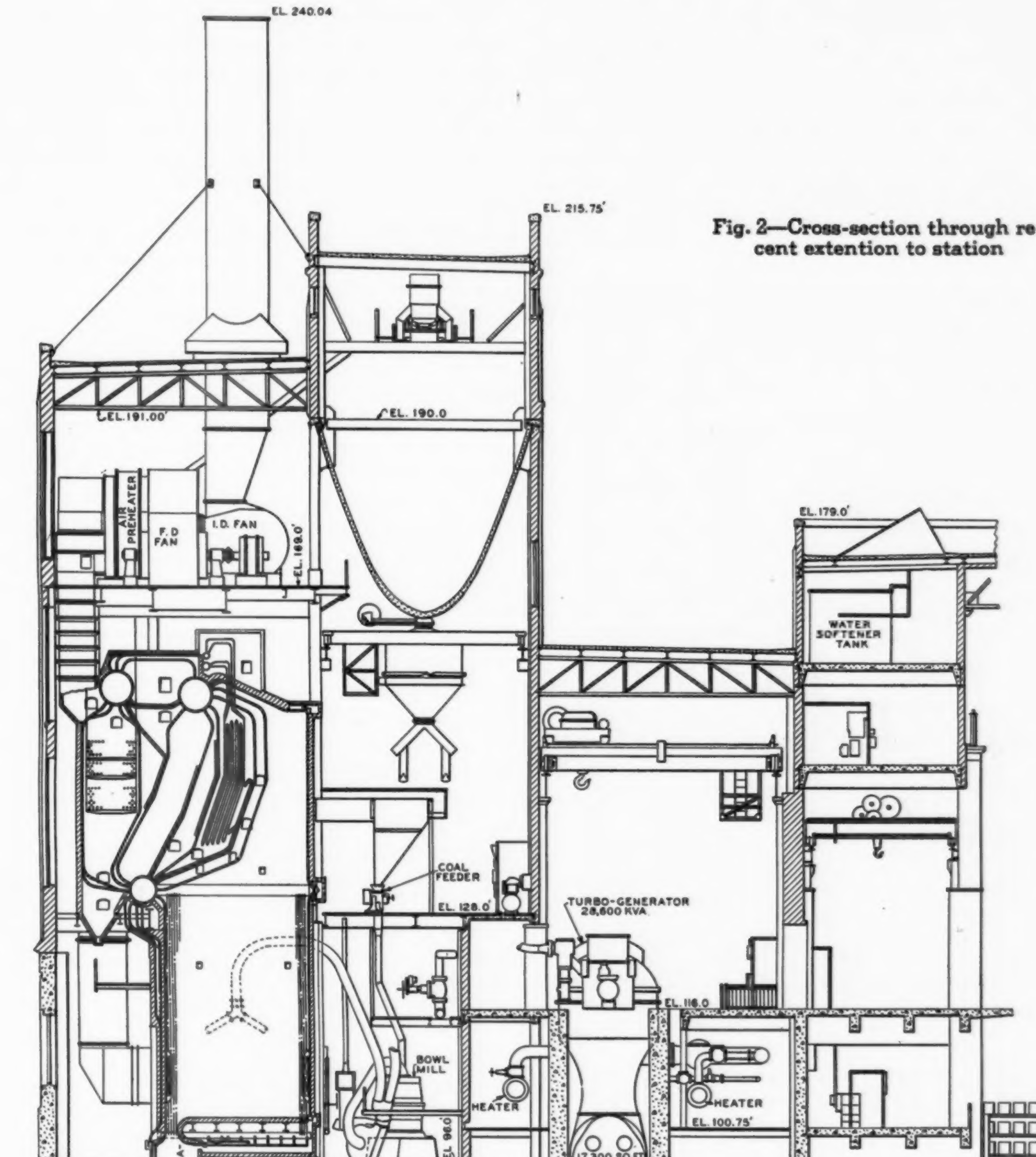

Fig. 2—Cross-section through recent extention to station

sufficient to supply the entire fuel requirements of the new boiler.

The tubes in the furnace bottom are covered with cast-iron blocks. Ash is removed in viscous form through an opening fifteen inches wide at the back of the furnace floor, this opening extending entirely across the furnace. The viscous slag drops into a water filled ashpit, where it is cooled to produce a cinder similar to the ash from a stoker. The ash is removed from the pit periodically by draining the pit and feeding the ash to the suction of an ash pump by means of hydraulic jets. During the period when the ash is being removed, the slag dripping from the furnace floor is cooled by water sprays in the upper portion of the pit.

The three pulverizers, each of 15,000 lb per hr capacity, are of the Raymond bowl-mill type. Each exhauster is directly connected to its mill so that both mill and exhauster may be driven by the same 150-hp. 1200-rpm motor. The average heating value of the coal is 10,400 Btu per lb. In order to provide the best possible mill foundations, simplify coal piping and afford space on the operating floor, the pulverizers were located in the boiler

room basement. Each is served by an independent coal feeder located on the boiler operating floor where it can be easily inspected and adjusted by the fireman.

Boiler Auxiliaries

The new boiler is served by a single induced-draft fan located above the unit. At maximum capacity this fan handles 212,000 cfm of flue gas at 407 F with a draft at the fan inlet of 17.2 in. of water. It is driven by a 900/400-hp, 720/514-rpm 440-volt, 3-phase 60-cycle motor, through a 42-in. variable-speed hydraulic coupling.

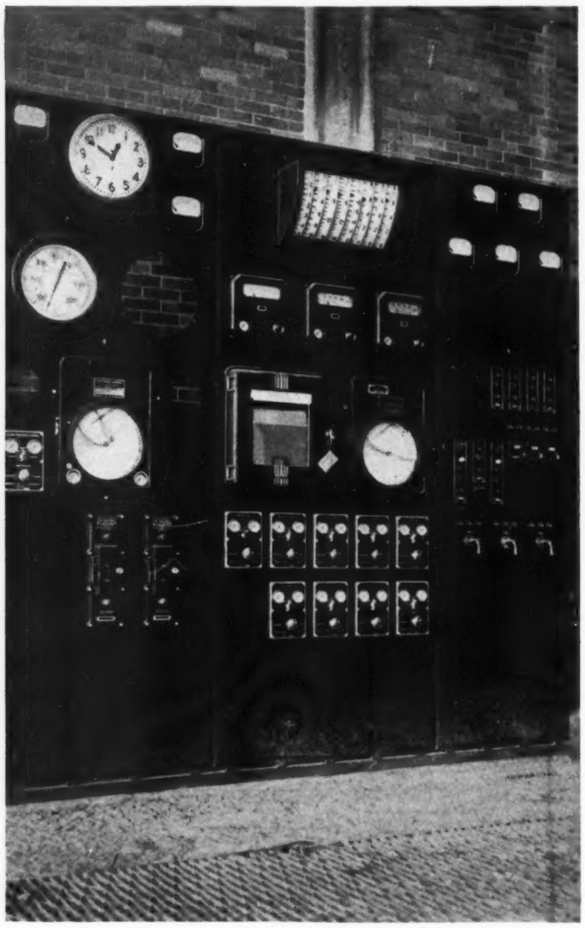

Fig. 3—Boiler room instrument panel

The speeds of the motor were selected so that the low-speed winding may be used in normal operation when the steam output of the boiler is below 225,000 lb per hr.

The fan blades have abrasion-resistant steel wearing pads formed over the inside edge of each blade and tack-welded to the outside edge. Stay rods in the fan wheel are protected by pipe sleeves. The fan housing, inlet boxes and gas ducts are made oversize to permit lining of these parts with concrete applied by means of a cement gun. This concrete is reinforced with bars and wire mesh securely anchored to the plates of the housing, inlet boxes and ducts. These special features of construction should greatly reduce maintenance caused by erosion from fly ash. The hydraulic coupling was selected rather than inlet vanes in order to reduce to a minimum the number of parts subject to erosion, and because previous experience in other plants has indicated that the erosion of parts in a variable-speed fan is appreciably less than in a fan operating under variable load conditions, but driven by a constant-speed or a two-speed motor.

The forced-draft fan, of 104,300 cu ft maximum capacity at 11.75 in. of water, is located adjacent to the induced-draft fan and air heater. It is equipped with inlet vanes and driven by a 300/125-hp, 1200/900-rpm motor. The blades of this fan are backwardly curved to produce a non-overloading power characteristic.

Due to the size and comparatively low voltage of the induced-draft fan motor, an auto-transformer has been installed with proper control equipment to reduce automatically the voltage at the motor terminals on starting, and also when the speed of the motor is changed. This arrangement limits the maximum inrush of current to approximately 1500 amp.

Two boiler-feed pumps, each of sufficient capacity to supply feedwater to the new boiler at maximum output are installed in the pump bay of the extension. Each is rated at 700 gpm against 2600 ft total head at 212 F. Double-suction impellers are employed throughout, thus insuring good hydraulic balance. Each pump is driven by a 700-hp 3600-rpm wound-rotor motor. The principal reason for employing this type of motor was to reduce the starting current. However, the motor controls are designed to permit variable-speed operation of the pumps, in order to take care of varying load conditions most efficiently. The pumps are designed for approximately 100 lb per sq in. greater excess pressure than required for maximum operation so as to provide for decreasing total available head due to wear between periods of overhaul. The variable-speed motors permit operation at reduced speed when the pumps are in best condition, to maintain normal excess of boiler feed pressure over the drum pressure.

The new boiler is equipped with complete Bailey air-operated combustion control equipment designed to maintain the best operating conditions whether the boiler is being fired with coal, gas or coal and gas in combination.

Valves and Piping

Carbon-molybdenum tubing, fittings and valve bodies are used in the high-temperature steam piping, and seating surfaces on all high-temperature valves are faced with stellite. Where joints were required in the steam piping, 900-lb Standard flanges with small tongue and groove facing were used. All high-pressure valves greater than 2-in. are flanged, and small drain valves were machined with socket ends for welding.

A novel arrangement of two reducing valves and one desuperheater was used to make the capacity of the high-pressure boiler available to operate the 400-lb turbines. In order to insure maximum flexibility, two reducing valves were installed. The valve which opens first has a venturi-type desuperheater installed at its outlet. The other reducing valve, which starts to open only after the first valve is nearly wide open, discharges steam beyond the desuperheater outlet. The thermostat which controls the water to the desuperheater is installed beyond the point where the discharge from the desuperheater joins the outlet pipe from the second reducing valve. Thus the temperature of the steam to the 400-lb header is always automatically controlled, but only one-half of the maximum flow of 300,000 lb of steam per hour passes through the desuperheater. This makes

it possible to use a smaller desuperheater which will control the steam temperature more accurately than a full-size desuperheater at low steam flows. Besides, the smaller desuperheater costs less.

The reducing valves are air-operated and controlled by two pilot regulators. One of these pilots is connected to the 400-lb header and normally controls the reducing valves to maintain a pressure of 390 lb in this header. In case of trouble in the 400-lb steam system which would produce an excessive steam demand on the 900-lb header, the first pilot will open wide both reducing valves. When the pressure in the 900-lb header drops to 800 lb the second pilot, which is connected to the 900-lb header, takes control of the main valves and operates them as back-pressure valves to maintain the pressure in that header at 800 lb, but still pass to the 400-lb header that portion of the high-pressure boiler capacity not required by the high-pressure turbine.

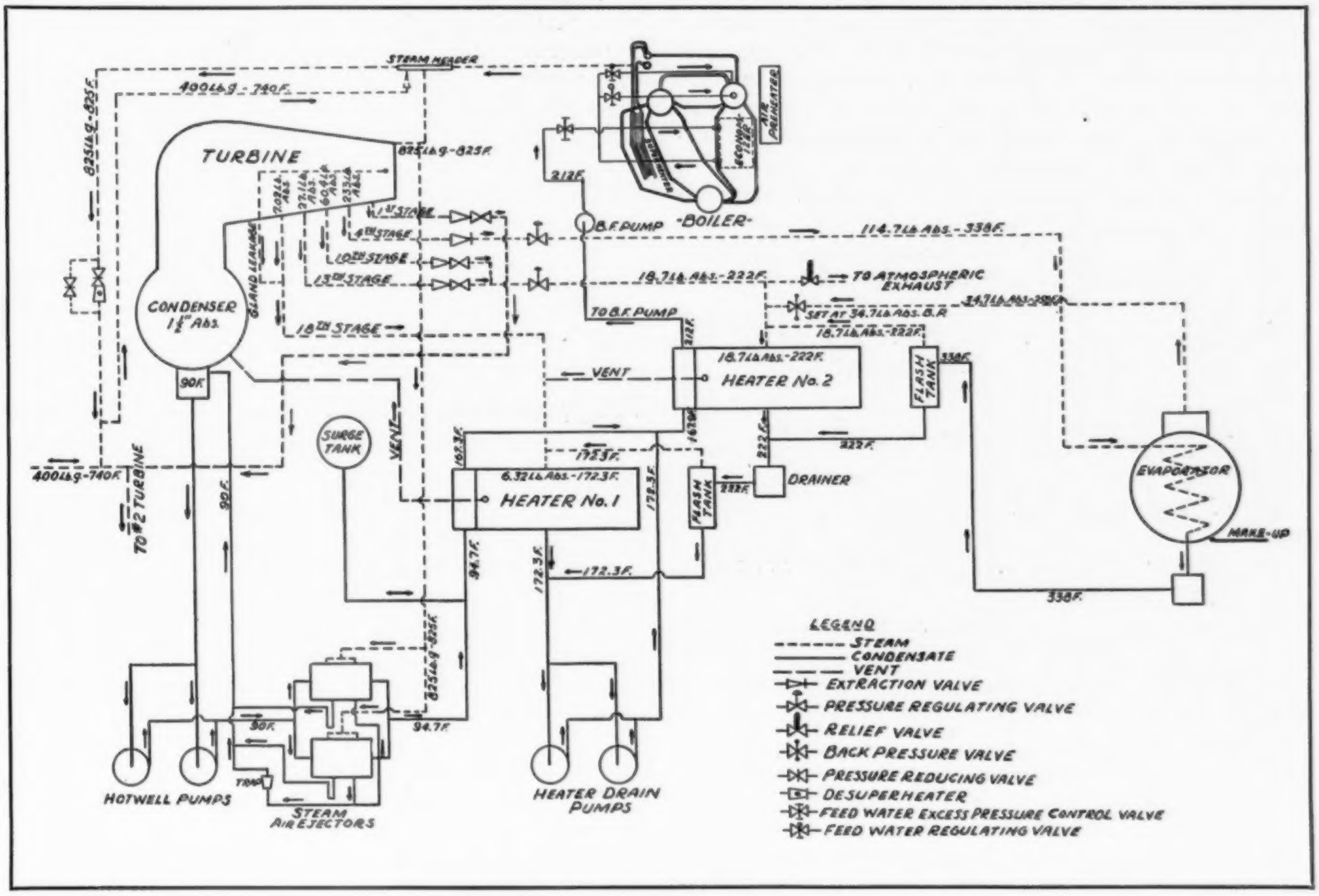

Fig. 4—Heat-flow diagram of high-pressure extension

Building

In the original installation the four boilers were placed two on each side of a common firing aisle. The original turbine and the second turbine were installed in a turbine room located between the boiler room and the river. The turbine shafts are all parallel to the firing aisle; hence, after the second turbine was installed the turbine room was approximately 72 ft longer than the boiler room.

Despite its greater capacity, it was found possible to put the new steam generating unit in a space the same size and shape as that occupied by one of the older boilers. Therefore the boiler room was extended two bays, using the same column spacing in both directions as was used in the original installation. This provided space for the new boiler and for a future boiler, both on the side of the firing aisle farthest from the river. The space between the firing aisle and the existing turbine room, which would have been used for two more boilers, if the boiler arrangement used in the original installation had been continued, was made a part of the turbine room. The new turbine-generator was installed in this space.

The suspended parabolic coal bunker construction employed in the original installation was duplicated, using the same cross-sectional dimensions and the coal conveyor over the original bunker was extended to serve the new bunker. The height of the building extension over the boiler and bunker was made the same as in the original part of the building, and the section over the new turbine was made considerably lower.

This method of extending the building for the new equipment not only reduced building costs, due to the decreased space required, but further reduced this cost because the construction was far enough from the river to eliminate the necessity of a cofferdam.

In order to install the turbine and its auxiliaries in the space provided, the condenser was located with its tubes parallel to the turbine shaft. A single-pass condenser with 17,300 sq ft of surface, made up of $^7/_8$-in. diameter tubes 26 ft long was selected, as a long narrow condenser was best suited to this arrangement. The condenser was set in the turbine room at an elevation slightly lower

than its final position before the turbine foundation was built. The reinforced-concrete foundation was then built around the condenser. After the turbine was erected the condenser was raised to its final location and attached to the turbine exhaust nozzle by welding. The entire weight of the condenser is supported by the turbine exhaust nozzle.

Two horizontal circulating pumps serving the second turbine were removed and replaced by two vertical propeller type pumps which were built into the existing 42-in. suction pipes that had served the pumps removed. The capacity of the pumps removed was approximately 26,000 gpm each. The new pumps have a capacity of 55,000 gpm each and can supply sufficient water for the condenser of the new unit as well as for the condenser which the horizontal pumps had served. Therefore the expense of installing additional suction pipes was avoided, and no additional space was required for circulating pumps for the new unit.

The resulting decrease in building volume required per pound of steam generated per hour, and per unit of installed capacity is shown in the accompanying table. This tabulation does not include the switchhouse, screen house or the space, unoccupied at present, which has been provided for a future boiler. Although there has been a substantial reduction in space occupied by turbine-generators and turbine auxiliary equipment per unit of capacity, a considerable proportion of the reduction in total plant volume per kva of capacity has been due to the reduction in building space required per pound of steam generated.

COMPARISON OF BUILDING SPACE PER UNIT OF STEAM AND ELECTRIC GENERATING CAPACITY

	Original Installation	Plant Immediately Preceding 1936–1937 Addition	1936–1937 Addition Only	Plant Including 1936–1937 Addition
Steam generating capacity, lb per hr	360,000	560,000	300,000	860,000
Space occupied by steam generators and their auxiliaries, cu ft	908,000	908,000	269,000	1,177,000
Space occupied by steam generators and their auxiliaries in cu ft per lb of steam per hr	2.52	1.62	0.89	1.37
Capacity of main and auxiliary generators (kva)	26,875	55,446	31,696	87,142
Space occupied by turbine-generators and their auxiliaries, cu ft	632,000	1,187,000	239,000	1,426,000
Space occupied by turbine-generators and their auxiliaries in cu ft per kva	23.6	21.4	7.5	16.4
Total volume of main power house (exclusive of space provided for future equipment), cu ft	1,540,000	2,095,000	508,000	2,603,000
Total volume of main power house in cu ft per kva	57.4	37.8	16.0	29.9

Conclusions

The latest addition to Riverside Station shows that superposition is not the only way of increasing the economy of an existing steam-electric generating station. The important features may be summarized as follows:

1. The new boiler and turbine-generator operating at 825 lb per sq in. 825 F steam conditions produce power at the lowest total cost considering fuel cost, load factor and investment charges in this particular case.

2. Steam may be extracted from the new turbine to the older 400-lb steam header, thus making the new unit share to some extent the advantages of a superposed turbine in increasing the economy of the older turbines.

3. The new unit may be operated alone when the load is light. This would not be possible in a superposed installation and makes this unit much more economical under light load conditions than a superposed plant.

4. The new unit may be operated with steam from the old boilers, thus making it unnecessary to install more than one high-pressure boiler to insure maximum availability of the new turbine. This makes better use of existing investment in lower pressure boiler equipment than is usually possible with superposition.

5. The arrangement of turbine governing mechanism, piping and steam-pressure reducing and desuperheating equipment makes the capacity of the high-pressure boiler instantly available to supply steam to the 400-lb header in case of trouble with the high-pressure turbine, and also makes it possible to maintain the new turbine in operation, without loss of load, with steam from the 400-lb boilers in case of trouble with the high-pressure steam generator.

The equipment described was placed in operation late in 1937. Operation to date has shown that the expected increase in plant economy due to this equipment has been fully realized.

Program for A.S.M.E. St. Louis Meeting

The summer meeting of the American Society of Mechanical Engineers will be held in St. Louis, June 19 to 23, inclusive. Informal conferences and committee meetings will occupy Sunday and on Monday morning the first of two Fuels Sessions will be held. Papers at this session include: "A Down-Draft Conversion Burner for Domestic Furnaces," by J. R. Fellows; "Coal Carbonization and Its Relation to the Smoke Problem," by M. D. Curran; and "Smoke-Density Measurements," by H. E. Bumgardner.

On Tuesday morning there will be a Boiler Feedwater Session at which the following papers will be presented: "Carbonaceous Zeolites—An Advance in Boiler-Feedwater Conditioning," by Howard L. Tiger; "Boiler-Water Treatment—New Methods for Preventing Embrittlement," by F. G. Straub and T. A. Bradbury; "Boiler Operation as It Affects Prime Movers," by S. E. Tray; and "The Behavior of Sodium Sulphite in High-Pressure Boilers," by R. M. Hitchens and J. W. Pursell.

A combined Hydraulic and Power Session is scheduled for Tuesday afternoon at which will be presented two papers, one on "Trends in Design of Large High-Pressure Boiler Units" by John Van Brunt, and the other "Operating Methods and Problems of a Combined Hydro- and Steam-Electric System" by H. Harrington and E. B. Strowger.

On Wednesday morning the second Fuels Session will be held at which the following papers will be presented: "Fuels for Industrial Heating Furnaces," by Matthew H. Mawhinney; "Power-Plant Requirements of a Distillery," by H. L. Walton; "Experiences and Difficulties in Processing Coal," by L. C. McCabe.

A session on Welding and Flame-Cutting will comprise papers on "Oxy-Acetylene Surface Hardening," by A. K. Seemann; "Welding Applied to Plant Maintenance and Repairs," by H. R. Wass; and "Arc-Welding Costs," by E. W. P. Smith.

53,000-KW, 3600-RPM, Superposed Turbine for Waterside Station

By G. B. WARREN
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This is a detailed description of the 1200-lb, 900-F, G.E. turbine which will shortly go into service at Waterside Station of the Consolidated Edison Company, New York, exhausting steam at 200 lb to the older turbine units. Special features include a 3000-kw feed-heating turbine on the same shaft as the main unit, hydrogen generator cooling, double shell construction and the method of supporting the rotor. Materials entering into the construction of the unit, to withstand the high temperature and pressure, are discussed, as well as the control and fire protection features and the economies anticipated by this superposed arrangement.

Another milestone has been reached by the Consolidated Edison Company of New York, Inc., in its continual progress toward more efficient power generating equipment. This is the installation of the second 53,000-kw, high-pressure, high-temperature, hydrogen-cooled turbine-generator unit which has been superposed over the low-pressure turbines already in operation in Waterside Stations Nos. 1 and 2. This unit has been designed and manufactured by the General Electric Company and together with a few other recently installed machines represents the culmination of a turbine and generator development which has been carried out over a period of several years.

This unit is arranged to supply all the steam required by approximately 64,300 kw capacity of the 200-lb., 600-F, low-pressure turbine units now operating and, in addition, will supply sufficient steam at the proper pressures to heat the returning feedwater on its way from the condensers back to the new high-pressure boilers.[1] In so doing, it will use slightly more than a million pounds of steam per hour at 1200 lb gage pressure and 900 F and will produce approximately 53,000 kw. This 53,000 kw will be produced at a net heat rate chargeable to the turbine heat cycles of about 3500 Btu per kw hr over and above that which would have been required to operate the 64,300 kw of low-pressure turbines as they formerly operated.

Taking into account the fact that the new boilers will have an efficiency which is better than that of the existing boilers, this unit should result in the addition of 53,000 kw of capacity with but slight increase in the total coal consumption of the plant, and with a resulting total output of energy of some 117,000 kw [2] where formerly only 64,000 kw were produced. It is, of course, not always possible to make increases of power plant capacity by such superposed turbines. Where the conditions are favorable, however, it makes possible the generation of new power in additionally installed capacity with extremely low fuel consumption per new kilowatt-hour produced. Such low fuel consumption is only rivaled by a water-power plant, but the initial investment cost of the superposed plant will be much lower than the usual water-power plant and comparable to a condensing steam plant.

One unique solution of a problem generally encountered in superposition undertakings has been worked out to meet the conditions in this station. This is in connection with the supply of steam for staged feedwater heating. The main low-pressure turbines in most plants where superposition of high-pressure turbines is economically feasible today were designed and built from 15 to 20 years ago. At that time the regenerative system of feedwater heating by extracting steam from the main turbine unit was not in general use, and very few turbines were arranged for the extraction of steam for feedwater heating. To adapt these older turbines for extraction is not only difficult and costly, but presents a rather definite hazard because of the detrimental effect of the steam extraction on the reliability of the buckets in turbines which were not originally designed for such extraction. Where it is desired to make the larger portion of the auxiliaries electrically driven, as was done by the engineers of the Consolidated Edison Company in this instance, it becomes necessary to work out a means of supplying steam for heating the feedwater at two or three pressures. Such means must permit utilization of the available energy in this steam from the boiler pressure down to the point of its use in the heaters. This has been accomplished in this instance by arranging a small "feedwater heating turbine" in tandem with the main superposed back-pressure turbine, and supplying this feedwater heating turbine with steam from the exhaust of the main turbine.

[1] See Combustion, September 1937.

[2] The author is, of course, referring only to this second unit. If the first unit, of like capacity, which is now in operation, be also taken into account these figures will be doubled—Editor.

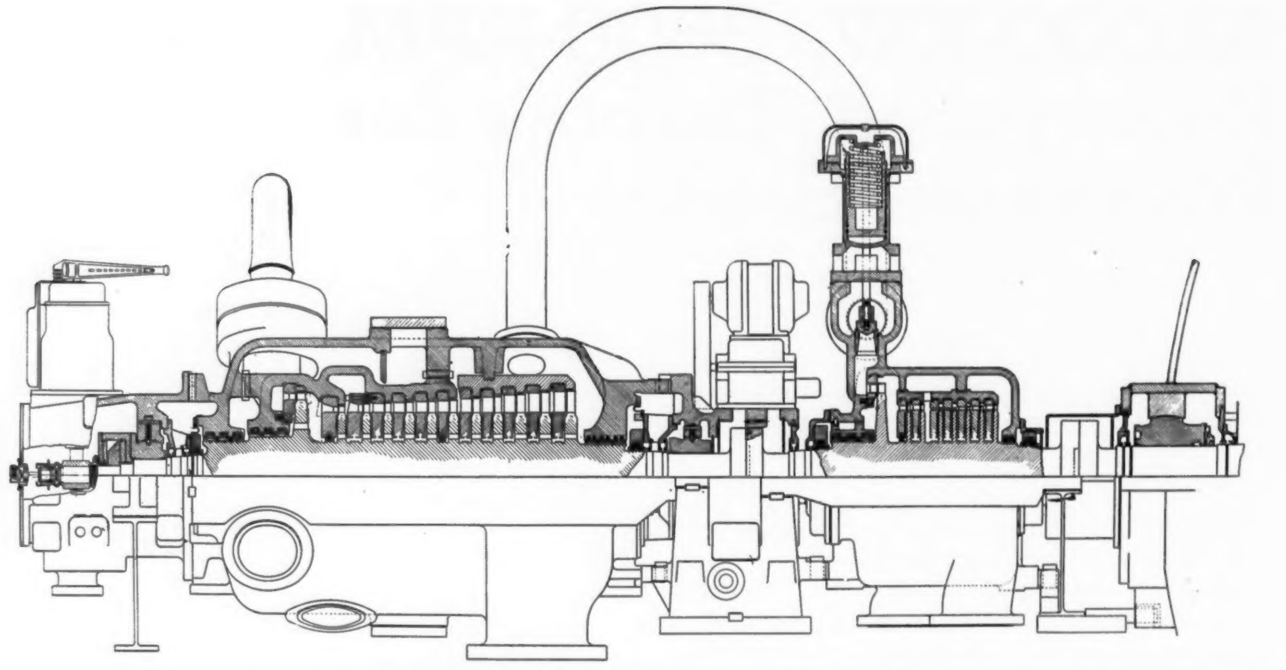

Fig. 1—Longitudinal section through Waterside turbine—high-pressure element, 50,000 kw; extraction element 3000 kw

Although this article deals primarily with the turbine part of this new unit, it is primarily the successful development of large 3600-rpm generators that has permitted the development of these new high-speed highly efficient turbines for high pressures and high temperatures. The development of these generators is a story in itself. It would be of value to point out, however, that this final result is the culmination of a long step-by-step progress in which each new achievement permitted the successful design of a larger and still larger generator at these speeds. The final series of steps from an 18,750-kva generator built in 1932 to the 58,889-kva generator of this present machine is the joint result of the increases resulting from higher strength rotor forgings, the further increases permitted by the use of aluminum windings for the rotating field windings, and the reduction in losses and increases in capacity permitted by hydrogen cooling, all of which features are incorporated in this generator. Furthermore, hydrogen cooling has resulted in an increase in efficiency to such an extent that the efficiency of this generator, including excitation but not including the mechanical bearing losses, is very close to 99 per cent at full load.

The increase in turbine speed from 1800 to 3600 rpm has resulted in a great reduction in the diameter and weight of the turbine rotor, a reduction in the number of stages necessary, an increase in the radial height of the nozzles and buckets for this high density steam, and a reduction in the size and weight of the casings required. All of this means a turbine with greater possible efficiency and more suitable for high temperature conditions and high steam pressures.

General Arrangement of Unity

Fig. 1 shows a longitudinal cross-section through this main turbine and the low-pressure feedwater heating turbine, and Fig. 2 shows side and front elevations of the unit. From these views it can be seen that the unit consists of the main high-pressure turbine, the smaller feedwater heating turbine which produces some 3000 kw of the total capacity, the main generator and

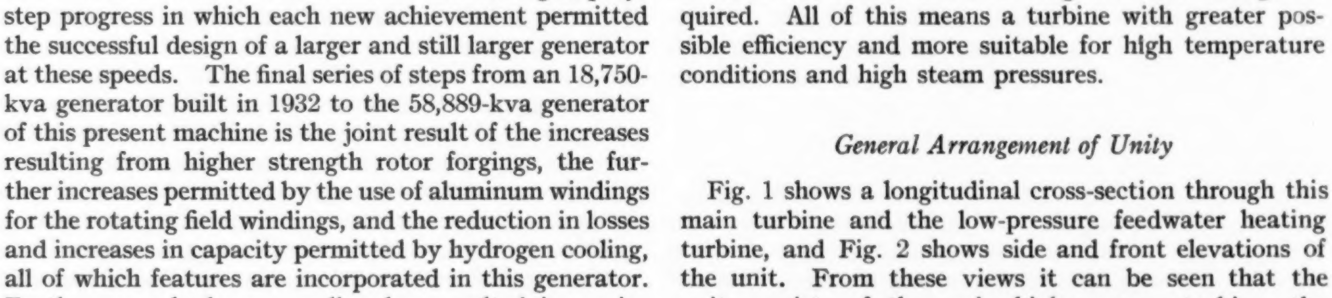

Fig. 2—Front and right-side elevations of turbine-generator unit

the gear-driven exciter. The main turbine has 12 stages and the feed-heating turbine 8 stages. The two turbines are anchored to a common cast-steel pedestal and are free to expand, the one in one direction and the other in the other, with the outboard or high-pressure end of the main turbine and the generator end of the feedwater heating turbine supported on flexible plates which permit free expansion.

The two turbines and the main generator are connected by solidly bolted flange couplings forged integrally with the several rotors, and the rotating element is located by the thrust bearing on the forward or high-pressure end of the main turbine. In this connection it is rather interesting to note that the feed-heating turbine has no bearings of its own. The main turbine is carried on two bearings, and the generator on its two bearings, making four main bearings in the unit. The feed-heating turbine rotor is supported by simply being coupled at either end to the couplings of the main turbine and the main generator, respectively. This results in a unit of the minimum possible overall length and of the greatest simplicity. The complete absence of the wearing parts which would be required in flexible couplings, and the elimination of the two bearings and thrust bearing which would be necessary were the feed-heating turbine rotor equipped with bearings of its own, should increase reliability. In dismantling or assembling the two turbine rotors will generally be handled as one unit, although it is possible to remove them separately.

Double Shell Design

The main high-pressure turbine has been designed in accordance with the "Double Shell Principle" used on a number of recently constructed turbines which have been built to operate at high pressures and high temperatures. The axial cross-section in Fig. 3 illustrates this construction. This arrangement embodies an inner casing surrounding the first seven stages in the turbine and in which the steam is expanded from some 1200 lb down to about 450 lb at the end of the seventh stage group.

This inner casing has its own bolting flange, and is surrounded by an outer casing which likewise carries its own bolting flange and which supports, by means of suitable construction, the last five stages of the turbine and the exhaust openings. The main high-pressure packing is divided into two sections: one section held in the inner shell, and the other, in the outer shell. The leak-off from the intervening space passes around in between the inner and outer shells and back into the turbine at the seventh stage. The pressure of this stage determines the pressure between the two shells at the various loads, and the flow of steam from the intermediate leak-off from the high-pressure turbine so provided maintains a relatively constant temperature in the spacing between the inner and outer shell. This temperature is substantially lower than the incoming steam temperature and thus protects the shell bolting against the higher temperature.

The inner shell is supported within the outer shell in such a way as to permit radial and longitudinal expansion, at the same time keeping the two shells accurately located with respect to each other and the rotor.

By means of this double shell construction the total pressure difference, and hence shell loading, is divided between two casings and two bolting flanges, each of which can be thinner and narrower, respectively, than would be the case if the entire pressure drop at the stresses entailed by these high temperatures were to be carried in a single turbine shell of usual design. It is believed that this will result in less shell distortion as a result of uneven heating, will not require so long to heat up, will permit simpler and more symmetrical castings and will result in materially less trouble from shell warpage over the useful life of the turbine.

Materials

In connection with the foregoing, the question of proper materials to use for high-temperature, high-pressure turbines is of great importance. It is, of course,

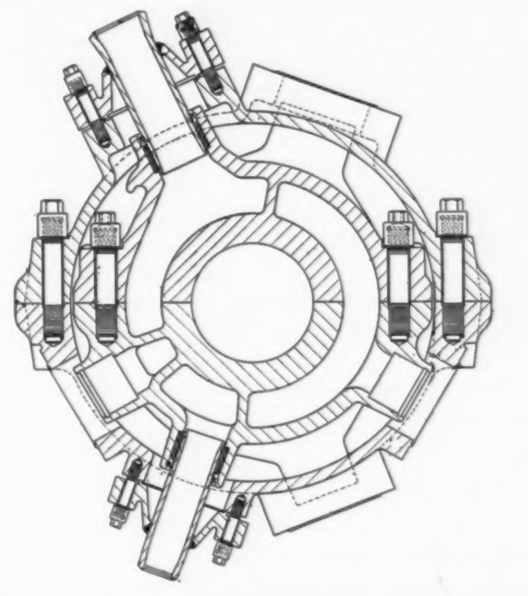

Fig. 3—Axial cross-section showing double-shell construction

so important that no high-pressure, high-temperature turbine would have been possible were it not for the successful result of a long investigation and research program carried out with the object of: (1) developing usable alloys of high strength for high temperatures which would be available at reasonable costs and (2) finding out what stresses could be put on these materials with reasonable expectation of continued satisfactory service over a long period of years.

This research program, which had been going on in a modest way, was given an additional stimulus in 1925 in the General Electric Company when it appeared that the limit of temperature, about 750 F, had been reached with the materials then available for turbine construction. By 1929 a full research program was underway to determine the safe working stress to which various materials could be put at temperatures from 800 to 950 F, as well as to determine what materials, heat treatments, etc., would give the best "low creep" properties. This work has been described in a number of papers presented over the past several years.[3]

[3] "The Effect of Temperature on Materials Required in Turbine Design," by S. H. Weaver, *G.E. Review*, Nov. 1930. "The Flow of Steels at Elevated Temperatures," by F. P. Coffin and T. H. Swisher, *Trans.* A.S.M.E. 1932, "Metals at High Temperature—Test Procedure and Analysis of Test Data," by E. L. Robinson, *Trans.* A.S.M.E. 1933. "An Automatic Creep Test Furnace," by P. H. Clark and E. L. Robinson, *Metals and Alloys*, Feb. 1935. "Stability of Steels under Stress up to 1,000 F as Viewed by a Turbine Designer," by Ernest L. Robinson, *Metal Progress*, Sept. 1935.

By the end of 1930, this development had progressed to such a point as to indicate that there were steels of moderate cost which would be suitable for large steam turbine parts and which had the ability to withstand working stresses at temperatures between 900 F and 950 F, of such magnitude as would permit the design of turbines for these conditions. The results obtained, however, showed that materials of the same composition often differed very widely in behavior and that excellent performance could not always be duplicated. It was not clearly understood what alloys, and in what metallurgical conditions the materials should be to permit attainment of desirable properties with certainty in the finished product. By 1934, however, sufficient tests were available from specimens which had been subjected to controlled metallurgical conditions to permit assurance that materials could be produced at will having satisfactory properties.[4]

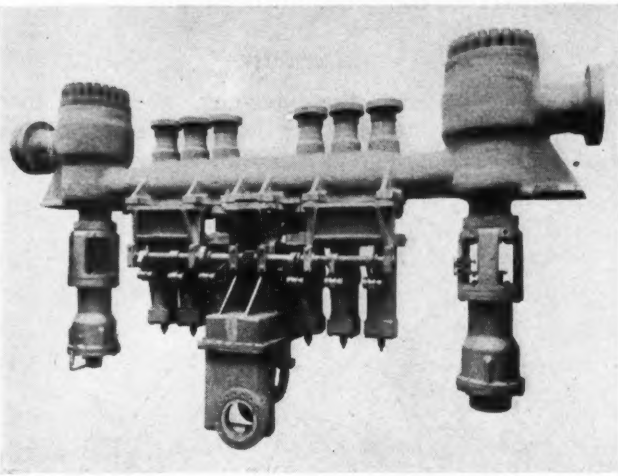

Fig. 4—Hydraulic gear and steam-admission-valve casing unit

These tests indicated that a carbon-molybdenum cast steel having approximately $^1/_2$ per cent molybdenum content would be satisfactory for turbine shells, especially when heat treated for high-temperature service. The 12 per cent chrome-iron alloy without molybdenum content appeared satisfactory for the bucket material throughout the turbine in view of the stresses involved. The nozzles of the high-pressure section were, however, made of 15 per cent chrome material with molybdenum added for strengthening at high temperature and with an extremely small percentage of aluminum added to reduce the air hardening which would otherwise take place following welding.

[4] "The Creep of Steels as Influenced by Microstructure," by L. L. Wyman, *Mechanical Engineering*, October 1935. "The Creep Curve and Stability of Steels at Constant Stress and Temperature," by S. H. Weaver, *Trans.* A.S.M.E. 1936.

With these materials and the added factors of safety presented by the double-shell construction, it was believed that turbines for high pressures and high enough temperatures would be entirely practicable for successful operation without resuperheating.

Control and Stop Valves

From Figs. 2 and 4 can be seen the two stop valves and the six controlling valves located under the main high-pressure turbine and connected thereto by six flexible steam connections. Four of these flexible steam pipes connect to four nozzle groups ahead of the first stage, and when these four controlling valves are open there is produced an output of approximately 45,000 kw in the complete set, the load of maximum economy. To obtain loads in excess of this, the two additional controlling valves are opened and admit steam at full boiler pressure and temperature into the steam belt of the inner shell surrounding the second stage.

All controlling and stop valves have streamlined disks and seats of a type which have been in use on hundreds of valves in G.E. turbines over a period of more than 10 years. Although originally developed to reduce pressure drop it has worked out that these valves have given service with less difficulties from leakage and cutting than any type of valve which had previously been used. The streamlined character of the flow together with the nearly spherical shape of the valve disk at the point of contact, and the resulting narrowness of the seat area of contact when closed, seems to give the above favorable result.

The control valve manifold is welded to the flexible pipes between it and the turbine and, with the exception of the two flanges in the vertical run of the upper pipes, as shown in Fig. 2, the high-pressure joints of these supplying pipes are all welded to the turbine as is apparent in Fig. 3.

The bolted joints shown in Fig. 3, where the pipes enter the turbine casing, are at the lower pressure of the space between the inner and outer casings. The steam is fed into the inner casing through a projection welded to the incoming steam pipe and packed with a special steel packing between this pipe and the inner shell of such construction as to permit a certain amount of radial and sidewise movement with negligible leakage.

Another feature of the stop valve which may be of interest is in connection with the design of the bolting of the large bonnet or cover required to permit access to the strainers which are located in these stop valve casings. Such bolted joints have ofttimes in the past been subject to some difficulties, particularly if the steam temperature should be suddenly reduced, as by a "slug" of water passing through the valve from the boiler with a resulting chilling of the bonnet flanges without a corresponding

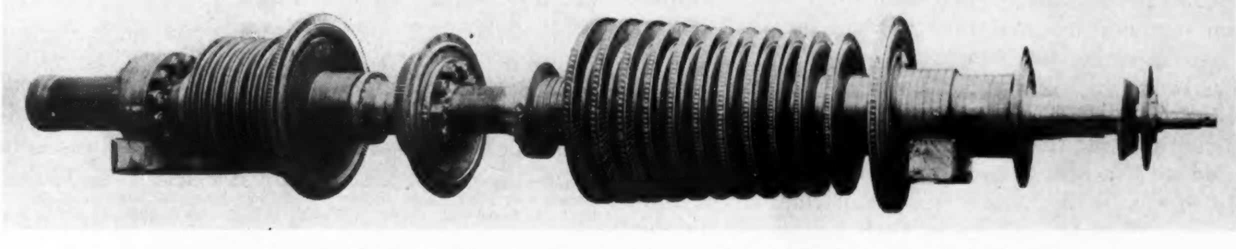

Fig. 5—Coupled high- and low-pressure rotors with wheels integral with shafts

chilling of the bolting. This has in the past been followed almost inevitably by leakage which required a remaking of these large joints. In order to overcome this, several of the large stop valves built during the past few years for severe steam conditions have been provided with especially long bolts, and thick washers of approximately the same cross-section as that of the bolts have been installed under the nuts. This has resulted in tripling the effective elasticity of the bolt and washer as compared to the usual shorter bolt and nut combination. Based on the operation of a number of these stop valves in service, several of which have satisfactorily withstood several "slugs" of water without leakage, it is believed that this problem has been met by this construction.

The controlling valves of these machines in common with a number of other recently constructed machines of this type are unique in that they are mounted inverted as compared with the usual arrangement and are below the valve manifold. This permits the controlling valve stands, the camshafts and the numerous bearings of the controlling mechanism to operate at a much lower temperature than would be possible with this mechansim above the hot steam manifold.

Governing, Hydraulic Valve-Operating Mechanism and Safety Features

The turbines are provided with three operating governors and one emergency governor. The centrifugal speed governor is driven by a worm gear from the high pressure end of the main turbine in the usual manner.

Two back-pressure governors are provided. One is arranged in conjunction with the speed governor so as to permit opening or closing the main controlling valves as a function of the back pressure on the main turbine exhaust or the frequency of the electrical system being supplied, and also in terms of the setting of the adjusting motor control on the back-pressure governor or the synchronizing motor on the speed governor. In addition, a back-pressure governor is provided on the exhaust of the feed-heating turbine so as to open or close the controlling valves of the low-pressure turbine as a function of the exhaust pressure supplying the lowest heater, which is maintained at approximately 5 lb gage.

The stop valves, of which there are four, two high pressure and two in the cross-over pipes supplying the low-pressure turbine, can be opened or closed by hand and are all automatically tripped closed by the action of the over-speed governor.

To operate the six main controlling valves, passing somewhat more than 1,000,000 lb. of steam flow per hour, and which must maintain accurate and safe control of a turbine of this output and low rotor inertia, requires an hydraulic servo-motor of great power and speed.

The entire hydraulic control mechanism together with the main turbine back-pressure governor is located in an oil-tight case under the controlling valve manifold and supplied with oil from the oil pumps located in the oil tank under the exciter end of the generator as shown in Fig. 2. The high-pressure supply pipe from these pumps in the main oil tank to the case surrounding the hydraulic cylinder under the valves runs on the inside of the oil drain line. Thus, there are no high-pressure oil pipes exposed whose breakage might lead to a fire hazard.

The main oil tank is located under the exciter end of the main generator, far removed from the hot surfaces, in order to reduce the risk of oil fires. This location has permitted combining the pump drive gears and the 2-to-1 reduction gear for the exciter drive.

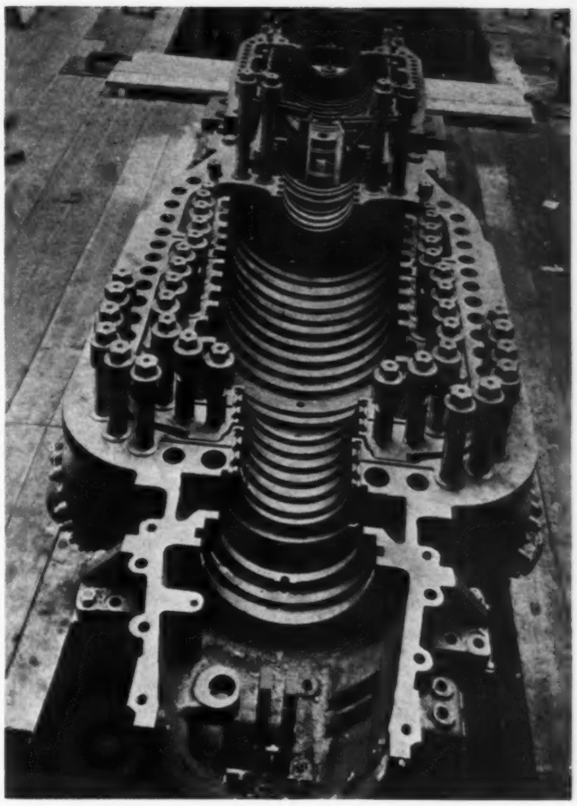

Fig. 6—Lower-half shells being aligned in shop

The lubricating oil pumps and oil coolers are also located in the main oil tank along with the high-pressure oil pumps supplying the main hydraulic system described above. The bearing supply pipes carrying oil at moderate pressure pass from these pumps, through the coolers and to all of the bearings through the respective bearing drain lines. In this way the entire oiling system is adequately protected against all possibility of a fire resulting from broken high-pressure oil supply lines.

Fig. 5 shows the high-pressure and low-pressure turbine rotors coupled together. These rotors are each made from a solid alloy steel forging which has been carefully heat treated and thermally stabilized to maintain straightness under varying temperature conditions. The wheels are machined integrally with the rotor.

The buckets are sturdy and are provided with extra strong attachments. These attachments embody many refinements of design and construction which, judging from experience, should make them withstand successfully the high centrifugal and intermittent steam loads to which they are subjected. When it is realized that the entire high-pressure turbine rotor weighs approximately one-fifth of a pound per horsepower of developed output, it can be appreciated that these buckets are subjected to very severe loads.

Manufacture

The earlier stages of the initial assembly of this turbine in the factory are shown in Fig. 6, and in the Waterside Station in Fig. 7.

Fig. 8 shows one of the nozzle diaphragms in process of manufacture. This diaphragm is fabricated by welding

properly shaped and spaced stainless iron alloy nozzle partitions of a non-air hardening type of material in between an inner web and an outer ring. The result is a finished nozzle diaphragm of integral structure, great strength and high efficiency. The solution of the problems of shrinkage alone involved in the fabrication of such a structure has required a continuous study by the manufacturing and engineering organizations responsible for production of these parts extending over a period of some seven years.

The rotor shown in Fig. 5 with its attached buckets is made from steel forged to most exacting specifications, subjected to extremely searching tests for thermal stability at temperatures up to and beyond the operating temperature—after both rough and finished machining—and in addition is subjected to the "magnaflux" method of inspection for minute cracks or flaws throughout its surface. The buckets are all individually subjected to the same type of "magnaflux" inspection for cracks.

The valve and turbine casings in addition to being subjected to the usual hydraulic pressure tests are examined minutely and all flaws or suspected flaws chipped out and re-welded, and a liberal use of X-ray facilities is made whenever inspections indicate a suspicion of an internal defect. The welding of all such defects is carried out under careful supervision with a covered welding wire depositing metal of substantially the same composition as the body of the casting, and under controlled preheated conditions.

The welding of the main turbine stop valves and the valve controlling manifold, Fig. 4, into a solid piece was performed in the factory following rough machining and under preheated conditions, and was followed by an oven strain-relief anneal before final machining of the stop valves or controlling valves.

The welding of the piping between the controlling valve manifold and the turbine was carried out in the power station by the same contractor who is doing all of the main station welding under the supervision of the insurance company inspectors, and was followed by strain relief anneal in place.

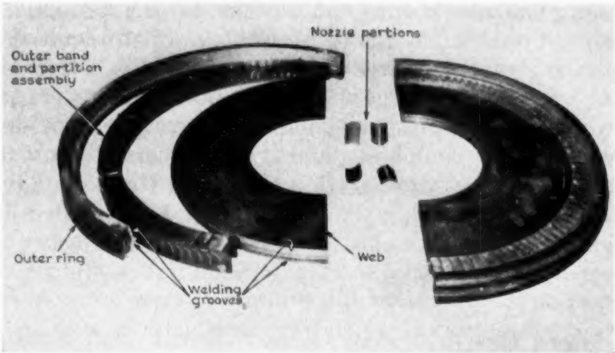

Fig. 8—Turbine diaphragm showing, at left, half ready to be assembled, and at right the half completely assembled

Other Machines of Similar Construction

Ten other double-shell turbines for high pressures and high temperatures, including one at 2300 lb and 940 F, have been built or are being built at the time of this writing. Double-shell construction which has also been described in a previous article,[5] was originally designed with the object of permitting the construction of turbines to operate at 1000 F. There is nothing which has been observed so far in the operation or inspection of these machines designed for somewhat lower temperatures that would indicate that this objective cannot be attained as soon as the demands of the rest of the art make such requirements necessary. In the meantime, however, the comparatively large number of machines now being installed to operate at 900 F to 950 F should provide the basic experience necessary before taking this further step.

[5] "New 40,000-KW, 3600-RPM Superposed Turbine for Logan," by G. B Warren, *Power*, June 1937.

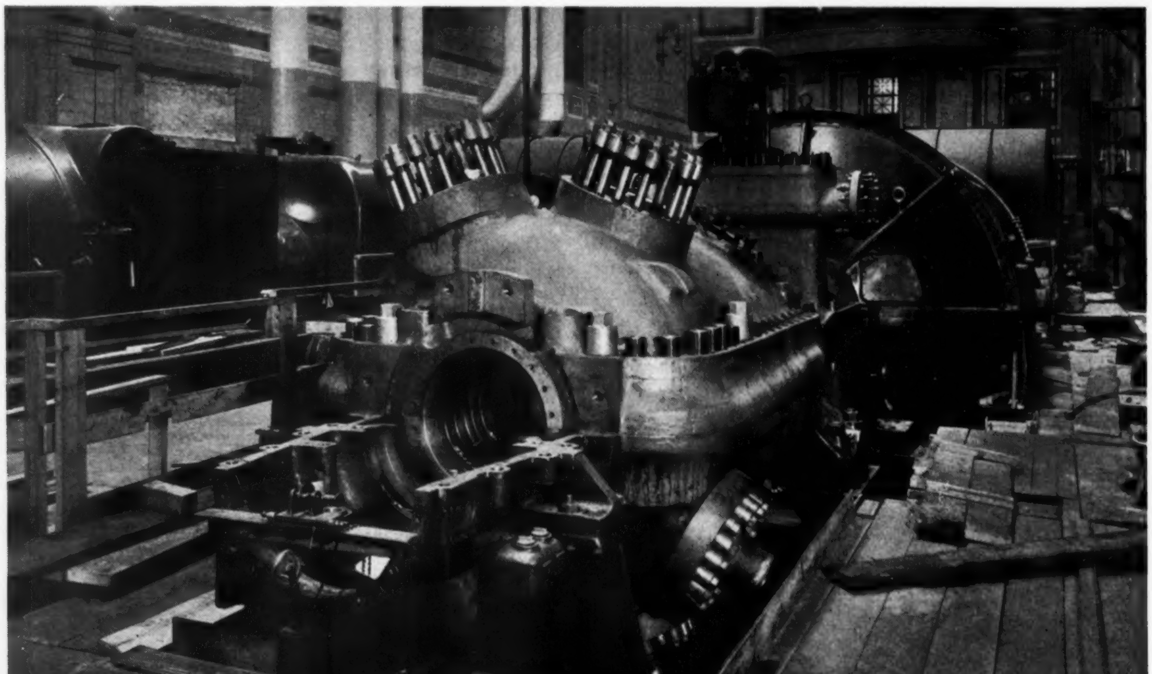
Fig. 7—Turbine being erected in Waterside Station

METALLURGY of POWER PLANTS

By A. E. WHITE
Director of Engineering Research,
University of Michigan

This is an abstract of a paper given before the Midwest Power Conference at Chicago, April 13 to 15, 1938.[1] It discusses metals used for boilers, boiler tubes, stoker tuyères, soot blowers, economizer tubes, superheaters, valves and fittings. The writer also discusses the need for new types of materials to meet the growing demand for those that will withstand increased pressures and temperatures, as well as prove resistant to caustic embrittlement and corrosion.

THE shells of all modern boilers today are made of either open-hearth or electric-furnace steel. Formerly, a good share of this steel was of a type known as "open" or "effervescing," although now most of it is of a grade known as "killed" steel. This latter type, namely, "killed" steel, is apt to be more sound and generally freer from manufacturing defects than the open steel.

Most of the plate material used in drums is of the plain carbon type, although a steel carrying 0.5 per cent molybdenum is becoming increasingly popular. This is due to the fact that this steel is somewhat stronger than plain carbon steel, and especially that it has better properties at elevated temperatures.

Although boiler plate at times undergoes some corrosion, it is usually thick enough so that, with proper boiler feedwater treatment, it is seldom seriously affected by this condition. Beyond question, the two most serious difficulties encountered with plate today, from a power plant operating standpoint, are the troubles due to aging and to caustic embrittlement.

Aging is by no means so serious a problem as that of caustic embrittlement. As may be inferred from the name, aging implies loss of ductility after exposure to a suitable temperature for a given time. This is especially noted in metal which has been strained. Aging is doubtless due to dissolved gases in the metal which agglomerate and migrate to the grain boundaries, producing, thereby, zones of weakness, provided time and temperature conditions are favorable.

Caustic embrittlement has received a great deal of attention during the past several years. Outstanding work has been done in this field by Parr and Straub of the University of Illinois, and splendid work is now also being done under the general direction of the Boiler Feedwaters Committee of the American Society of Mechanical Engineers in collaboration with the Bureau of Mines.

Various theories have been advanced to account for the deterioration of metal by this phenomenon. Without doubt, it is of the corrosion type; one in which the corroding medium dissolves away the grain boundaries, producing resultant brittleness, and, when allowed to proceed for a sufficient time, is accompanied by ultimate failure of the metal.

Whether it is a straight chemical action, a chemical-fatigue action or a chemical-stress action is a matter of doubt. It would appear, however, that it is more a matter of chemical-stress than a straight chemical action, because its effects are found in stressed sections. Real progress has been made in this field recently, but the problem is far from solved.

Also, one must make sure that in the operation of drums and other metal parts there is no tendency for any great temperature-stress differential. If such a tendency exists, one is apt to find, over a period of years, pronounced checks developing in the surface of the metal wherein the temperature differentials have occurred.

Boiler Tubes

Plain carbon steel, made according to the open-hearth or electric-furnace process, is the material used almost exclusively for boiler tubes. These tubes are of the open- or killed-steel type. An open steel is one in which the gases have not been completely removed by a final treatment with deoxidizing agents and, therefore, when it is cast into an ingot, it does not pipe appreciably. It has small gas pockets, if properly made, close to, but not at the surface of the metal. Killed steel, on the other hand, is one which has been completely deoxidized so that when it cools in the ingot it pipes, and these pipes have to be removed. Below the pipe the metal is sound. Although both open and killed steel may be used in the production of tubes, and although many tube mills prefer open steel because of its greater ease in working, it is believed that wherever possible killed steel should be used because of its greater soundness and freedom from segregation.

Stoker Tuyères

Stoker tuyères are at present made of cast iron and are giving fair service, although the development of a completely non-fusible, non-warping alloy for this purpose would be gladly received. To date, however, no com-

[1] Proceedings of this Conference have been printed and are now available at $2 per copy by addressing Dean L. E. Grinter, Armour Institute of Technology, Chicago.

mercial alloys of this type have been developed. There are some grades of low-alloyed cast irons in which the carbon and its form are controlled. These steps help the situation, but do not cure it.

Soot Blowers

Soot blowers are located in a portion of the boiler where they receive a considerable amount of heat. Made of plain carbon steel, they warp and scale badly. Manufacturers of these parts have given this matter considerable study and to date the most acceptable alloy is one which contains 20 per cent or more of chromium.

Economizer Tubes

Tubes for this service are, for the most part, of plain carbon steel inasmuch as conditions, from the standpoint of heat and pressures, are not unduly severe. In some instances economizer tubes have undergone rather rapid deterioration due to corrosion. This condition is apt to be rather severe when the gas temperatures are below the dew-point. Usually this can be controlled by operation. It would, of course, be desirable to have a metal which will not be subject to corrosion for this type of service. There are such metals, but their cost at the moment is too great to justify their use. Copper-bearing tubes are slightly superior to plain carbon-steel tubes, although the difference in life between the two types of tubes is hardly sufficient to justify the selection of the copper-bearing tubes.

Superheaters

Superheaters have been used to an appreciable extent only since 1910. At present superheaters are made with steel tubes covered with fins, or plain-carbon or alloy steel tubes without any protection or heat absorbing covering. A few years ago 18 per cent chromium steel was used, but since this metal develops brittleness at operating temperatures, its use was discontinued. It was then replaced by high-alloyed steels of the KA2 type, which carries about 18 per cent of chromium and 8 per cent of nickel. This latter steel would doubtless find much more general acceptance if its cost were lower, since it has good resistance to creep at elevated temperatures and is strongly resistant to the oxidizing influence of gases.

The present tendency is to find a low-alloyed steel which will have excellent strength over a long period of time at elevated temperatures, such, for example, as 1000 to 1100 F, with suitable resistance to oxidation. A number of steels have been brought out for this purpose, one of which carries around 0.75 per cent silicon, 1.25 per cent chromium and 0.5 per cent molybdenum. Another is a straight low-carbon 0.5 per cent molybdenum steel. Many other alloy combinations have been developed, including a 4 to 6 per cent chromium alloy. This last one, however, is finding more favor in oil refineries than in power plants for the reason that it is relatively resistant to the corrosive crudes with which it comes in contact. Its strength at elevated temperatures is not greater than the strength of the steels previously mentioned. It is also more expensive. Therefore, its use in power plants is limited.

There is also a growing appreciation that the high-temperature properties of these alloys are not entirely dependent upon chemical composition. In fact, this point will be understood when it is stated that different heats of 0.5 per cent carbon-molybdenum steel showed creep stresses that would be sufficient to produce one per cent elongation in 100,000 hr at 925 F, varying from 5000 to 18,000 lb per sq in., with a number of stresses from other heats varying between 11,000 and 12,000 lb per sq in. The heat that showed the 5000-lb stress has been admittedly recognized as unrepresentative and therefore should not be considered. Yet, its composition was the same as the composition of the other heats, the major point of difference being in methods of manufacture and mass. The stresses in the heats varying between 11,000 and 18,000 lb all took place in supposedly representative stock having essentially the same chemical composition. These differences, therefore, can be explained only on the basis of differences in melting practice, grain size and constituents—that is, whether the carbides be of the pearlitic, sorbitic or spheroidal type; whether the constituents in the steel show a banded structure; and whether the steel is clean or dirty. All of these are factors which influence the properties of the metals at elevated temperatures.

Valves, Flanges and Fittings

In the early days of steam power generation, valves, flanges and fittings were made of cast iron, malleable iron and bronze. With the rise of operating pressures and temperatures, these materials became unsuitable for this service. Steel has come into almost universal use and the critical parts of valves, such as the stem, seat and disk, are now made of special metals or of metals processed by nitriding, plating or welding. Valve stems are sometimes plated and the seats and disks are made of stainless steel, nitrided steel or by welding stellite to these parts.

Valve bodies are usually made of cast steel, although there is a trend toward low-alloyed steels containing such elements as molybdenum, silicon, chromium and nickel. One very popular cast steel at the moment carries 0.5 per cent molybdenum.

Some of the major defects in castings used for fittings are blow holes, slag inclusions, checks and cracks. Those engaged in the design of fittings can be extremely helpful in reducing these defects, particularly the checks and cracks which occur where there is pronounced change in cross-section. As a general rule, no castings should be designed in which there are sharp fillets or pronounced changes in cross-section. All castings should be slowly cooled from the casting heat. They should then be normalized by being brought up to the required heat slowly, held for a sufficient time, usually of the order of one or two hours per inch of metal thickness, and cooled uniformly in still air, followed by a draw at around 1200 F.

A certain amount of welding has to be done on most castings, although, if the defects are of a major type, it is better to scrap the casting than attempt to weld it. Whenever welding is done, the casting should be stress-relieved by a draw at around 1200 F.

Materials for the Future

In the next decade, it is probable that no very fundamental changes will take place in the types of metals for central station use. Methods of construction may change. Welded joints are today replacing riveted

joints. Pipe and other sections are now joined by welding rather than by the use of flanges. It is quite probable that further material improvement in the rolling in of tube sheets will take place. Superheaters and all of the fittings connecting the superheater to the turbine will be made of alloy steel, because these various parts will be subject to high temperatures, and material with a higher creep value than found in plain carbon steel must be used.

All fittings will doubtless be constructed of low-alloyed steels. The bodies of valves will be of these same materials; valve stems will be protected against oxidation by nickel or chromium plating; valve seats and disks will be of stainless steel, nitrided steel or stellite, preferably stellite.

All turbine shell castings and all turbine shafts will be made of low-alloyed steel. Turbine blades will be made of stainless steel and, in the lower temperature zones, of $3^1/_2$ per cent nickel steel.

Conclusion

It is safe to say that never in the history of metallurgy have those engaged in the production of materials for power plants worked more assiduously for the production of materials of higher and better quality. As never before, the manufactured products are being surrounded with added safeguards. Various concerns producing metals for this purpose are engaged in a more forward-looking and more comprehensive study of metals than formerly for the purpose of finding metals which will better suit conditions than has been the case in any previous time.

Testing Turbine Materials for Creep

Before a metal can safely be used in a modern high-speed turbine its creep under working conditions must be known. In the case of blades the metal is subjected to the combined action of high-temperature, centrifugal force and steam impact, and any appreciable creep after a few years' use will cause rubbing because of the extremely close clearances employed. The steam inside a turbine at 850 F is so hot that the metal glows a dull red, yet many turbines are now operating at steam temperatures in excess of 900 F. The necessity for guarding against creep also applies to casings, bolts and other parts that may be affected by high temperature.

In the past each sample of metal was placed in an individual furnace and heated while carrying a heavy weight. Periodically over several weeks the amount of creep was measured by means of mirrors which reflected onto a scale the degree of stretch between two marks on the samples. One man was kept busy watching five tests over several weeks.

Such old style testers were accurate but were not designed for the day when industry required one hundred or more simultaneous tests of different materials. The third of a battery of unique electric furnaces for studying creep has just been completed at the Westinghouse Research Laboratories. Each of these, designed by P. G. McVetty, combines the facilities of sixty old style creep testing machines and thus makes it possible to conduct 180 simultaneous tests.

Each machine is a heavy alloy steel block housed in a

Three newly-completed creep machines at the Westinghouse Research Laboratories, each of which can simultaneously test sixty samples at 1000 F of prospective material for turbine blades, bolts, casings or rotors.

three-walled cylinder taller than a man and supported on a foundation of sand (see accompanying photograph). In order to retain the heat inside the furnace, the outer shell is made of concentric sheets of polished nickel and aluminum separated by powdered silocel. Sand was used in the six-foot-deep foundation pit because of its ability to minimize the effects of vibration which are known to hasten the creep of metals. To keep the sand warm and dry, the engineers equipped the pit with its own electrical heating unit.

Three electric windings on the metal core of the furnace produce temperatures up to 1000 F and a photoelectric cell maintains the temperature within 10 deg or less by automatically operating a resistance which controls the electric current. The cylinder revolves once an hour in order to distribute the heat equally to all parts of the furnace.

When all three units are in operation, the operator will be able to "plug in" by means of a telephone switchboard and determine exactly how the heat is being distributed inside the furnace. One hundred and twenty-five pairs of wires connect thermocouples in the furnaces with instruments for measuring and recording the temperatures.

Each heating core has twelve spaces for holding twelve 20-in. test samples which may be subdivided into five sections to make sixty tests. Dial gages connected with comparison rods extending through the top of the furnace measure the relative vertical displacement of the rods by the samples which may be "loaded" by weights and levers to carry 50,000 lb per sq in. of metal under test.

But for a double check, the machine is equipped with a circular track and a micrometer microscope called an "extensometer." A laboratory worker welds two platinum spots or targets at the top and bottom of the sample metal, scratches very fine lines on the spots and fastens the sample metal in the furnace. When it is time to take a measurement of the creep the cylindrical shell is revolved until the sample is opposite two quartz windows which pierce the $10^1/_2$ in. wall. The microscope is rolled in place on the track, peers through the quartz windows and measures the distance between the two platinum targets. Its measurements are within one one-hundred-thousandths of an inch from perfection.

The engineers repeat the readings daily for approximately three months, charting the results as a gradual curve. Thus in three months they discover means of estimating how the metal will creep during the next twenty to thirty years.

World Power Conference

A sectional meeting of the World Power Conference will be held this year at Vienna, where delegates will assemble on August 25 for a week of discussion touching on all phases of power supply to consumers. The papers and discussions will deal with the supply of energy for agriculture, small-scale industries, household purposes, public lighting and electric railways, with emphasis placed on the point of view of the consumer. Members will exchange ideas on the distribution and application of energy, rates and schedules, market analysis, methods of finance, government action in the matter of energy supply and the influence of taxation.

Smoke and Fly Ash from Spreader Stokers*

By J. F. BARKLEY
Supervising Engineer,
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Speaking before the Annual Convention of the Smoke Prevention Association in Nashville, Tenn., May 17 to 20, the author cited conditions under which the emission of excessive smoke and fly ash is likely to occur with the spreader stoker and suggested means by which these may be controlled. Adequate length of flame travel, the employment of air or steam jets when operating at high furnace heat release and careful control of the fuel-air ratio will minimize smoke; whereas much of the fly ash, which settles in the back passes and breeching, can be prevented from going out of the stack by providing means for continuous removal or by the installation of water sprays in the base of the stack.

A SPREADER stoker might be defined as fuel-burning equipment in which an unpulverized fuel is spread or thrown into the combustion space, part of the fuel burning in suspension somewhat similar to pulverized fuel applications and part dropping onto the grate. In two general types the fuel is thrown in by revolving paddles, one using an overthrow and one an underthrow; other types blow the fuel in with air or steam air jets. From the standpoint of smoke emission, the spreader stoker operates somewhat like an oil burner, being very sensitive to adjustments and hence to the human element. A small turn of the hand, giving too much fuel feed for the given amount of air, immediately produces excessive smoke. Smoke has been produced with attendant adverse criticism, where the stoker has been placed in furnaces not appropriate for its use, or where the high load-carrying capacity of the stoker tempted firemen to carry higher loads and use fewer boilers than planned. Vertically baffled boilers usually do not provide the length of flame travel or the same kind of mixing provided by the longer horizontal combustion chamber of the horizontal return-tubular boiler.

Anthracite and semi-anthracite coals will give no trouble from smoke but all bituminous coals and lower rank coals may under certain conditions. For these coals, particularly if no auxiliary jets are used, I prefer space for a flame travel of at least 14 ft and such flame travel to be horizontally across the grate if possible. Heat releases from 20,000 to 35,000 Btu per hour per cubic foot of furnace volume should give acceptable results. To avoid furnace maintenance, furnace temperatures, not over 2400 F, ordinarily are desirable for the firebrick furnace. The amount of water cooling to be used on larger installations can be figured much the same as for other types of fuel-burning equipment, taking into consideration the CO_2 to be carried and the fusion temperature of the ash in the coal to be used. Much study has been given to the admission of overfire air where it may serve for metal cooling purposes and aid coal distribution as well as combustion. Where furnace conditions are poor, great improvement in smoke emission may be obtained by the use of steam jets or air jets properly set in the furnace. A cross-fire from jets at the front corners of the setting, aimed toward the rear of the grate, is quite effective in decreasing smoke. Certain installations that experienced difficulty in carrying a heat release of 18,000 Btu per hour per cubic foot of furnace volume, without making smoke and permitting a CO_2 of only 8 to 10 per cent, have been improved by the use of jets and enabled to carry heat releases from 25,000 to 50,000 Btu per cu ft per hr with a CO_2 of 14 per cent or more and an average smoke production of some six- to seven-tenths on the Ringelmann chart. Operating in a fashion similar to a pulverized fuel installation, such a stoker can emit a continuous shade of smoke if it is so adjusted.

From the smoke standpoint, such stokers should be given a proper size and shape of furnace, an adequate and effective system of control of air and fuel, intelligent operation and also provided with a smoke indicator so that the operator can see at all times what is being emitted from the stack. With such features properly taken care of in a conservative, not merely an optimistic, manner, this type of stoker should meet city smoke ordinances as well as other types. •

Fly-Ash Characteristics of Stoker

From the standpoint of fly ash the spreader stoker's characteristic of throwing fine coal up into space to be burned gives the smaller ash particles a good start on their flight with the products of combustion. The amount of fly ash leaving the furnace depends not only on the load and the total amount of ash, but also on the

* Published by permission of the Director, Bureau of Mines, U. S. Department of the Interior.

type of coal. Although anthracite and semi-bituminous coals give more ash carryover than some of the lower rank coals having around 10 per cent inherent moisture, it cannot always be judged exactly what relative carryover may be expected with a particular coal. Measurements have shown that from 25 per cent up to as high as 40 per cent of the total ash in the coal leaves the furnace. Accompanying this ash, combustible material was found in various ratios from as low as 10 per cent up to as high as 85 per cent, the higher value being for an installation using anthracite buckwheat No. 2.

Such fly ash settles in back chambers, in the breechings and in the base of the stack. Where too much is permitted to accumulate in one place, such as along the bottom of the breeching, it may suddenly lift all at once and go out the stack, thus creating some nuisance. Keeping all passages clean is a great help in eliminating fly ash nuisance. Opening the door at the base of the stack will sometimes cause a mass of the fly ash to lift. At a few plants this difficulty has been solved by installing a water spray at the base of the stack. This spray is turned on just previous to cleaning. Collecting hopper arrangements may be provided in back chambers and passes in the boiler, some well-designed installations having an ejector that returns the fly ash to the combustion chamber for further burning. Simple forms of baffle-type cinder catchers may be installed in the breeching, and arrangements made to dump regularly. Cinder-catching types of induced-draft fans are applicable for the larger installations as are many of the present more complicated types of cinder catchers.

The spreader stoker has several advantages over other types of fuel-burning equipment but inherent freedom from smoke and fly-ash emission is not one of them. Careful attention must be given to these items if there is to be enjoyed the advantages the stoker offers without getting into trouble with these weaknesses.

Obituaries

Edgar White Wagenseil, sales manager of Hagan Corporation, Pittsburgh, died suddenly on May 10, while engaged in his official duties. He was 54 years old.

Mr. Wagenseil was born at Port Huron, Michigan, and was graduated from the University of Illinois in 1905. He was first employed by the Illinois Steel Company as steam engineer and later was associated with the Chicago Smoke Abatement Commission and with the Burke Furnace Company. During the World War, he was an officer in the Aviation Division of the U. S. Navy Department and following the war he was connected successively with the Harrington Stoker Company, the Westinghouse Company, and later with Blaw-Knox. For the past six years he had been General Sales Manager of Hagan Corporation and its subsidiaries, The Buromin Company and Hall Laboratories, Inc.

Joseph B. Fowler, 49, special field engineer of the Cochrane Corporation, Philadelphia, Pa., died suddenly of a heart attack on April 15. Mr. Fowler, during his association with the Cochrane Corporation for the past 25 years, was responsible for many major developments and design improvements in the field of feedwater conditioning, deaeration and steam purification.

Electric Power Statistics

The Federal Power Commission has just issued its annual statistical report covering electrical power production and installed capacity in 3793 plants generating power for public use. These include privately owned utilities, municipal plants, electric railways, the Bureau of Reclamation, miscellaneous Federal and State projects and that portion of manufacturing plants selling power for public use. The number of companies and plants by class ownership, as of December 31, 1937, was as follows:

Class	No. of Companies	No. of Plants
Private Utilities	665	2692
Municipal Utilities	868	939
Bureau of Reclamation	9	12
Railways	25	31
Misc. Federal and State	27	42
Manufacturing	65	77

The installed capacity of these plants according to type of power generation was:

		Kilowatts	Increase over 1936, Per Cent
Privately Owned	Fuel	24,552,648	0.72
	Hydro	8,820,806	0.24
	TOTAL	33,373,454	
Publicly Owned	Fuel	2,005,120	14.54
	Hydro	1,653,538	7.43
	TOTAL	3,658,658	

Of the total, 37,032,112 kw, 25,873,720 represents steam, 10,474,344 hydro and 685,048 internal-combustion engines. Hydro power accounts for 28.3 per cent of the total installed capacity.

The production of electricity from these plants during 1937, in thousands of kilowatt-hours, was:

Privately Owned	Fuel	73,727,977
	Hydro	38,888,061
	TOTAL	112,616,038
Publicly Owned	Fuel	3,619,653
	Hydro	4,813,939
	TOTAL	8,433,592

The total output, privately and publicly owned, for 1937 was 121,049,630,000 kwhr of which 76,329,917,000 was generated by steam, 43,702,000,000 by water power and 1,017,713,000 by internal-combustion engines. Hydro power accounted for 36.1 per cent of the total. Thus while the net increase in total capacity from December 31, 1936 to December 31, 1937 was 565,060 kw, or 1.55 per cent, the output during this period increased 9 per cent.

The proportion of hydroelectric capacity to total capacity remained almost constant throughout the period from 1920 to 1937, ranging from 25.5 per cent in 1921 to 28.4 in 1937.

Measured in terms of pounds of coal and coal equivalent of other fuels, there was a slight increase in the efficiency of generating plants during 1937, the rate being 1.43 lb per kwhr as compared with 1.44 lb for 1936 and 3 lb for 1920. The coal burned during 1937 was 44,766,000 short tons, an increase of 6.5 per cent over 1936. During this period 14,143,000 barrels of fuel oil, an increase of 0.2 per cent, were burned, and 171,268,000 cu ft of gas, an increase of 9.7 per cent.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Centrifugal Pumps

A new bulletin giving complete specifications and operating characteristics of the Cameron Class GT two-stage centrifugal pump has recently been issued by the Ingersoll-Rand Company. These pumps are two-stage ball-bearing units designed to operate at modern motor, turbine and engine speeds. They are available in capacities from 100 to 2200 gpm for discharged heads up to 800 ft (350 lb per sq in.).

Evaporators

Engineers of central stations, industrial and process plants will be interested in a bulletin on evaporators for producing distilled boiler feed from hard or salty raw water, which has just been published by The Griscom-Russell Company. This booklet explains plant operating conditions for which evaporators are desirable, outlines the general features and advantages of evaporators for producing pure boiler feed makeup and describes the design of Griscom-Russell Scale-Shedding Bentube Evaporators, which are built in various types for a wide range of boiler capacities and pressures. A section discusses the association of evaporators with the plant heat balance. This section also explains the applications of single- and multiple-effect evaporators, and reducing-valve evaporator systems for process plants. A number of typical heat flow and heat balance diagrams are included.

Hydraulic Couplings

"Variable-Speed Hydraulic Couplings" is the title of a 16-page booklet, No. 3119, just issued by the Hydraulic Coupling Division of American Blower Corporation. These couplings, when applied to fans, centrifugal pumps or turbo-blower drive, provide a stepless speed control over a 5-to-1 range and when used for conveyors, pulverizers, reciprocating pumps or other constant-torque drives permit variable speed over a range of approximately 3 to 1. The coupling is built in sizes to transmit from 1 to 1000 hp and is adapted for use with manual control or with many types of automatic control. The booklet is fully illustrated and contains useful charts and dimensional tables.

Oil-Burning Equipment

Instructions for the care and operation of oil-burning equipment are covered in a 44-page book issued by The Engineer Company. The text is arranged in seven parts; Part I gives detailed operating instructions; Part II deals with requirements for efficient operation; Part III tells how to meet emergencies; Part IV takes up safety precautions in the care and handling of fuel oil; Parts V and VI give helpful information on the installation and proper maintenance of the Enco oil-firing system; and Part VII deals with the properties of fuel oil. The text, which in a sense is a handbook on oil firing, is fully illustrated and contains useful charts and tables.

Refractory Cements

Bulletin R-33, issued by Refractory & Insulation Corporation, describes R & I Moldit refractory cement for monolithic construction for temperatures up to 2800 F. Illustrations are included of its application for boiler baffles, hopper lining, air heater flooring and lining around openings into boiler settings, as well as numerous industrial applications.

Scale and Corrosion Control

"Organic Methods of Scale and Corrosion Control" is the title of a 16-page booklet issued by D. W. Haering & Company, Inc., manufacturing organic chemists. It represents a technical exposition of the application of organic chemistry in this field, expressed plainly in understandable language.

The booklet is profusely illustrated with graphs, formulas and equations of interest to the chemist and engineer responsible for scale or corrosion control in industrial operations. The application and properties of beta glucoside and the glucoside derivatives, including the recently developed hemi-phospho glucosate, is described in detail. The amounts of film inhibitor required for corrosion control are plotted against carbon dioxide, oxygen and hydrogen sulphide contents in a new graph.

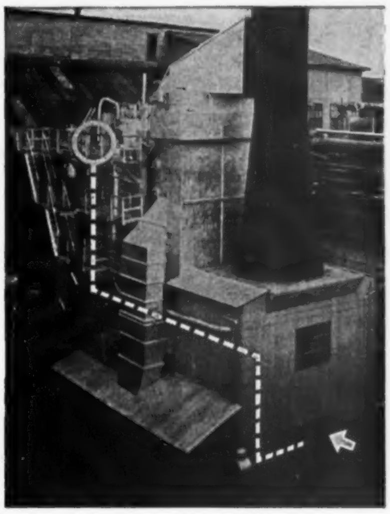
Steam Turbines

A new catalog on "Velocity-Stage Turbines," dealing with small steam turbines for driving generators, pumps, fans and other auxiliaries, has just been put out by the De Laval Steam Turbine Company. The design of these turbines has been especially adapted to the use of high steam pressures and high temperatures by locating the steam chest in the upper part of the casing cover where it is well removed from the bearings. Complete details of the turbines are given and illustrated by sectional wash drawings. Information on the De Laval double helical speed-reducing gear is included.

Valves

A new bulletin, No. 5-7000, dealing with forged and cast-steel valves in pressure ranges from 300 to 1500 lb per sq in., has lately been issued by the Hancock Valve Division of Manning, Maxwell & Moore, Inc. Valves of the globe, angle and check types are covered. Material specifications for the various valve parts are included for each type and class as well as detailed dimensions, list prices and weights. A tabulation of A.S.M.E. Service Ratings is appended.

Reliance EYE-HYE



brings your boiler water gage

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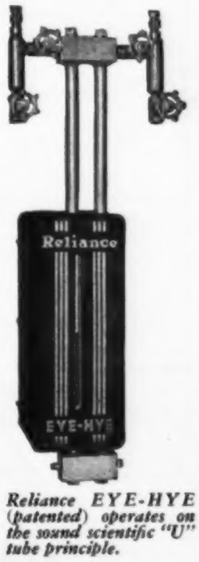
—anywhere you want it . . . for safe, convenient control

From a point at water column level on the boiler (in circle) on this high outside drum, two small tubes go down and around corners to the EYE-HYE in the control room (at arrow). Installation in power plant of the Fort Bend Utilities Co., Sugar Land, Texas.

● Why not have the same satisfaction in reading your boiler water level at a glance as you do with other vital controls? Stop climbing, squinting, or guessing at the all-important water level, by putting Reliance Remote Reading EYE-HYE right under your nose. There it shows, in brilliant green, the exact water level, just as accurately as the water column itself. Saves steps, saves time, makes it easy to maintain safe, efficient water level.

Dependable, trouble-proof, engineers in large and small plants find EYE-HYE easy to install. Two small tubes follow the most convenient route to the drum. There's an EYE-HYE for any pressure, high or low. Tested in actual use and proved more than adequate because of Reliance selection of tough metals, extra heavy construction. Moderate in cost and no upkeep expense.



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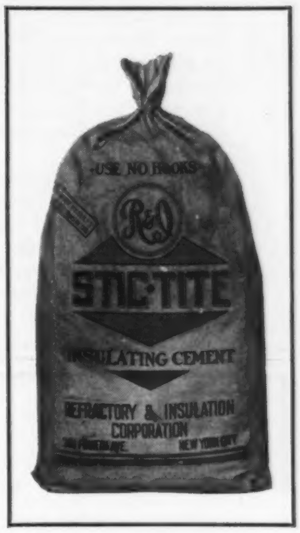

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STIC-TITE is an exclusive R & I insulating cement that has double the insulating efficiency up to 1800 deg. F. of any other similar cement not of the same composition.

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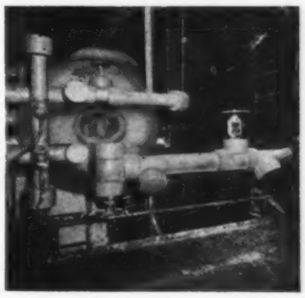

This drum head, piping, flanges, elbows, valves and fittings were completely insulated with Stic-Tite. No special skill required to produce this clean finish.

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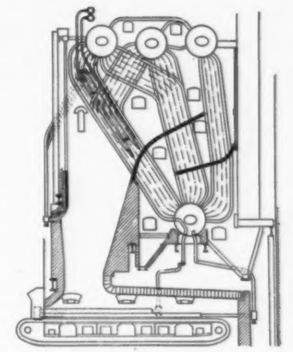

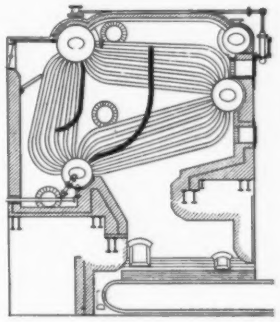

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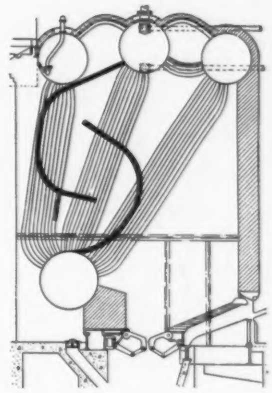

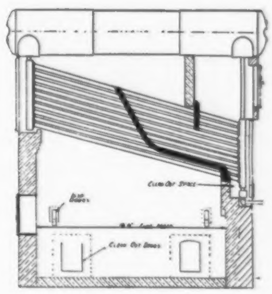

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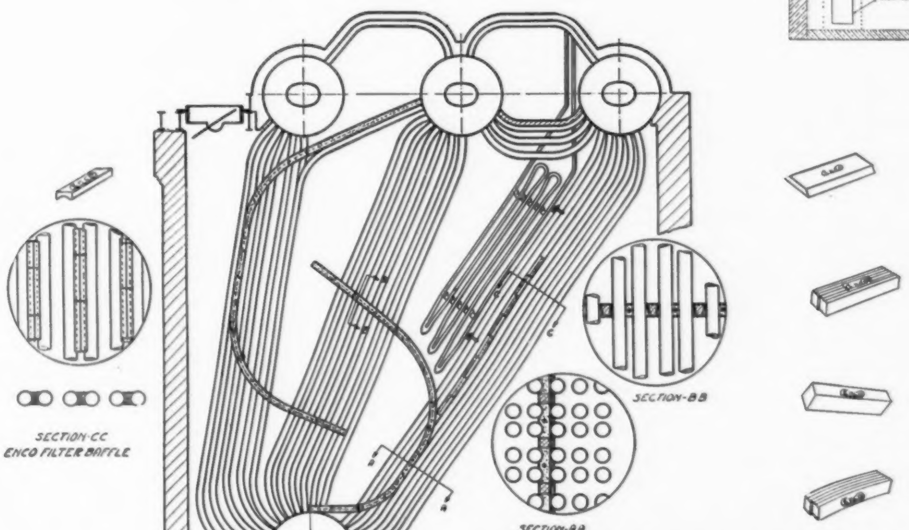

Drawing showing typical construction and the removable tile used to provide openings in the baffles for the removal of tubes.

Design and Construction covered by U.S. Patents 1,614,948—1,702,933—1,748,137 and 1,756,164.

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